STUDIES ON THE BIOLOGY OF SOME FRESHWATER FISHES

DISSERTATION

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This is to certify that the dissertation for M. Phil. degree in Zoology of the Aligarh Muslim University, Aligarh has been completed by Miss Masroor Fatima, under my supervision. It is original in nature and I have permitted the candidate to submit it for the award of M. Phil degree in partial fulfilment of the M. Phil. requirements in Zoology.

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Supervisor

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C O N T E N T S

INTRODUCTION

There is a growing recognition in recent years all over the world for a better understanding of aquatic environments and their productivity. Inland fisheries resources of India have traditionally played a significant role in human nutrition and have always been looked upon as an important source of livelihood for millions of fishermen who live close to rivers, lakes, estuaries and lagoons etc. Its importance has since taken a new dimension in the context of relentless population growth during the recent decade accompanied by sharp increase in demand of animal protein. Inevitably this has led to increased exploitation of the resources in many inland waters of the country.

Fishes, like many other forms of life, are of immense value to mankind. They have long been a staple item in the diet of many peoples. Today they form an important element in the economy of many nations. As the world population is galloping with the growing demand of protein rich food, considerable attention is being paid towards the management of fishes for increasing food production in every country. Many government institutions are busy in carrying out studies on fish biology and their propagation techniques. Nelson (1984) describes the importance of fishes to people. He explained that 'Fishes give an incalculable recreational and psychological value to the naturalist, sports enthusiast, and home aquarist". They are also the subject of international and domestic agreements and disagreements. They are used as general indicators of pollution, partly to the direct benefit of mankind and partly to protect what people consider a valuable and necessary part of their heritage and life.

The last two and a half decades have witnessed great productivity made in the field of fishery biology. Today biologists, especially the ecologists are busy to unveil the mysteries of nature by getting deeper into the ecology of fishes. The increase of fish production entirely depends on the proper management of the fishery resources, and one of the most important aspects of fishery management is the knowledge of natural history of the fishes which is known as bionomics. It is a part of ecology dealing with the biology of fishes. A detailed study on the biology of food fishes is an essential pre-requisite in the management and exploitation of the fishery resources. As Panikkar (1952) has rightly pointed out, 'It is futile to attempt fishery management without adequate knowledge of biology of the fishes concerned". So, it will be the fitness of things that the attention of the fishery scientists should focussed on the investigations relating to various aspects of life history like rate of growth, food and feeding habits, migration, age, size at first maturity, spawning grounds, time and duration of spawning, etc. A review of the literature reveals that most of the workers have confined their studies, on these line, on the marine food fishes, as these fishes contribute a major portion of the total fish production of the country. The marine fish in our country are landed throughout day and night, and the landing centres spread all along the coastline. The experimental fishing operations conducted by the Indian trawlers have already shown that coastal waters of this country support fisheries of a considerable magnitude. Notable studies made on the biology of marine food fishes are those of Chidambaram, 1950; Vijayaraghavan, 1955; Ganapati and Srinivasarao, 1957; Dhulkhed, 1962; Bannet, 1964; Kagwade, 1964; Radhakrishnan, 1964b; Balan, 1971; (on sardines); Murty, 1983 (on Sihar belly); Devanesan and John, 1940; Bhimachar and George, 1952; Noble, 1962, George and Banerjee, 1964; Luther, 1973; Doiphode, 1974 (on mackerels); Prabhu, 1955; Narasimhan, 1974 and 1983 (on ribbon fishes); Mohammed, 1955; Nayak, 1960; Krishnamoorthi, 1971 and Murty, 1984 (on thread fin fishes); Bapat et al., 1951; Pillay, 1953 (on Bombay Duck); Seshappa and Bhimachar, 1955; Groat, 1971; Seshappa, 1974; Datta and Das, 1983 (on Malabar sole); Kuthalingam, 1967 (on silver pomfret); Marichamy, 1972 (on short jaw anchovy); Desai, 1972 (on long finned herring) and Talwar, 1961 (on halfbeaks).

Appreciable amount of work has also been done on the biology of some economically important estuarine fishes. The work on estuarine fishes includes important contributions made by Jacot (1920), Pillay (1954), Sarojini (1957 and 1958), Luther (1963) and Thakur (1968) on mullets. Hora and Nair (1940a), Chacko et al. (1948), Chacko and Ganapathi (1949), Jones and Menon(1951), Pillay (1958), Pillay and Rao (1962), and Ramakrishnaiah (1972) elucidated the life history of Hilsa while Mookerjee et al.(1946) made a detail study on the food of estuarine fishes of Bengal.

An information on the biology of freshwater fishes, is still meagre. Carlandar (1950) and Lagler (1956) gave a generalised account on the biology of freshwater fishes. In India, Chacko and Kuriyan (1950), Chackraborty and Singh (1963), Natarajan and Jhingaran (1963), Chackraborty and Murty (1972), Ramamohan Rao and Hanumantha Rao (1972), Parameswaran et al. (1974), Hanumantha Rao (1974), Narayan (1982), Prakash and Gupta (1986) have studied in detail the biology of carps. Qayyum and Qasim (1964c), Saigal (1964), Bhatt (1968, 1970a, and 1971) and Parameswaran et al. (1971) have studied the life history of some cat fishes. Detailed study on the biology of murrels was reported by Alikunhi (1953) Marichamy (1974) and Kilambi (1986).

Keeping in view the paucity of information on the biology of important freshwater food fishes, attempts have been made at Aligarh to study the biology of fishes of this region. Some notable researches have already been done on the biology of murrels, carps and cat fishes (Qayyum and Qasim, 1964a, 1964b, 1964c; Kamal, 1964, 1967; Khan, 1972 and Chatterji, 1976). They have studied in detail the various aspects of life history of Ophicephalus punctatus, Barbus stigma, Callichrus bimaculatus Labeo rohita, Cirrhina mrigala, Catla catla, Labeo bata and Labeo gonius from different impoundments and rivers of Aligarh region. Khan and Siddiqui (1973), Mustafa (1976), Jafri and Mustafa (1977) reported food and food selective behaviour of Labeo rohita; Esomus danricus and Catla catla. Khan and Siddiqui (1973) elucidated the food selection of Labeo rohita (Ham.) along with its feeding behaviour in relation to other major carps. Food and feeding habits of Labeo bata, Labeo gonius have been studied by Chatterji (1974), and of Trichogaster fasciatus by Mustafa and Jafri (1978). Reproductive biology of some fishes havebeen reported by Qasim and Qayyum (1961 and 1963), Siddiqui et al. (1976a and 1976b). Mustafa (1978) described the length-weight relationship and condition factor of Esomus danricus from different environments. Chatterji et al. (1977a and 1979) described the morphometric character and age growth of Labeo bata. Tariq (1977), in Labeo calbasu and C. reba, has observed sexual dimorphism in certain morphometric characters.

Workers have also studied various aspects of biology of Indian mullets. Important contributions made are those of Hora (1939), Bhimachar (1945), Jacob and Krishnamurthy (1948), Sarojini (1951, 1953, 1957 and 1958), Pakrasi and Alikunhi (1952), Pillay (1953, 1954), Ranganathan and Natrajan (1969) and Rangaswamy (1973). Review of the literature shows that all of these studies are preliminary in nature and no comprehensive work has so far been done on mullets. It is, therefore, thought to make a detailed and extensive study on the biology of one of the species of Indian grey mullets, Mugil corsula (Hamilton). It is classified under the family Mugilidae of the order Mugiliformes. It is one of the great economically important food fishes of Indian freshwaters. Mugil corsula occurs in abundance far above the tidal influences in freshwater situation in the major Indian river systems like Ganga, Jamuna and Mahanadi etc. For study, the specimen were collected from Jamuna river with the help of cast net .

In order to have rational basis for the management and exploitation of the fishery resources, we must have a good knowledge of species composition of an ecosystem supporting the fishery. When a species is commercially exploited, it becomes important to know whether the catch come from a single stock or from several stocks which may or may not remain discrete entities. The intraspecific variations in the fish over the area of investigation is potentially an important matter from the stand-point of future management. The researches relating to the taxonomic identity of the intraspecific stocks which are generally referred to as "racial investigations".

These studies are based on the hypothesis that certain morphometric characters are associated with autonomous population.

In the present investigation, to assess the aforesaid detail, the growth rate of morphometric characters in relation to each other and to resolve the possibility of great differences between the regression of body parts of males and females from a single environment is carried out. The study of relative growth of body parts is one of the most fascinating subject of biology, and it is very essential in fish taxonomy. Considerable attention has been given on this aspect of biological studies by Krumholz and Cavanah (1968), Botros et al. (1970), Dias et al. (1972), Islam and Al-Nasiri (1978), Pillai (1983), Acharya and Dwivedi (1984). Pillay (1957), Radhakrishnan (1957), Sarojini (1957), Tandon (1962), Khan (1972) and Chaterji et al. (1977a) have followed the method of regression for the analysis of different characters to discrete the populations, races or stocks. Prior to assertain the significant differences in the regressions of various body parts from different localities, if any, it is necessary to resolve the possibility of great difference between the regression of body parts of male and female in each locality. The samples for the present work were collected from a single environment i.e. river Jamuna.

Another important part of the present investigations is the study of food and feeding habits of fish which is an important aspect of biology and fishery management. The study of food and feeding habits of fishes attracted the attention of fishery biologists from the beginning of the present century in view of the recognised importance of food and feeding habit as an environmental factor influencing the growth and distribution of fishes and success of their fishery. Therefore, a knowledge of the food and feeding habits of various fishes is advantageous in their proper management and exploitation. Most of the investigators have reported the food of the fish and its variation with season, sex and size of a single species in an environment. A great deal of work has been done on the food and feeding habits of fishes from Indian freshwaters. Bhatnagar and Karamchandani (1970), Khan and Siddiqui (1973) and Chatterji et al. (1977b) have studied food and feeding habits of Labeo rohita, L. fimbriatus, L. gonius and L. dero. Mookerjee and Ghosh (1945), Das and Moitra (1955b) have discussed feeding behaviour of major carps. Kamal (1964 and 1967) and Khan and Siddiqui (1973) reported food selection behaviour of young and adult major carps. Badola and Singh (1980) and Nair and Sobhana (1980) worked on food and feeding habit of Puntius, Tor and Barilus. Aravindan (1980) described the food selection and feeding behaviour of Trichogaster fasciatus and Tilapia mossambica. Recently Sampath and Pandian (1980) reported the food and feeding habits of Channa spp.

Studies on food and feeding habits of mullets in general have been carried out by Jacob and Krishnamurthy (1948), Pillay (1953), Sarojini (1954), Luther (1962), Prasadan (1970) and

Romer and Mc Lachlan (1986). Hora (1939) and Bhimachar (1945) described the surface feeding habit of *Mugil corsula* and their observation are based on the probable mode of origin of aerial vision and the structure of brain. A perusal of literature shows that although casual observations have been made on the food and feeding of mullets, very little information is available about the qualitative and quantitative aspects of food of *Mugil corsula*, which is also regarded as one of the highly proteinecious and economically important freshwater fish. Therefore, present investigations are undertaken to get a clear picture of food and feeding habits of *Mugil corsula*.

The present work deals with two important aspects of biology of *Mugil corsula* (Hamilton), namely morphometric studies, food and feeding habits, and has been presented in the form of this dissertation for M.Phil degree of Aligarh Muslim University. Its scope and results can be assessed by going through the following Chapters.

DESCRIPTION OF THE FISH

Mugil corsula (Ham.) belongs to order Mugiliformes and family Mugilidae. The systematic position of the fish is as follows:

Phylum	:	Chordata
Sub-phylum	:	Vertebrata
Class	:	Gnathostomata
Sub-class	:	Actinopterygii
Order	:	Mugiliformes
Family	:	Mugilidae
Genus	:	*Mugil*
Species	:	*Mugil corsula*

Salient features : Body torpedo shaped, pointed anteriorly. Slightly laterally compressed. Dorsal profile is straight but ventrally it is bulging out forming a convex structure. Eyes of the fish are without adipose lids and elevated with their upper margin above level of the flat inter-orbital space. Head with its profile nearly straight and depressed. Upper jaw over hung by the snout and is longer than the lower. Upper lip thick and notched for receiving the tubercle of the lower lip. Both jaws are having a row of very small and minute teeth. Caudal fin is slightly emerginate. Scales are ctenoid covering most portions of the body except fin and eyes. The fish is steel grey dorsally and lighter along the abdomen. Dorsal and caudal fins are greyish.

Geographical distribution: *Mugil corsula* is found in fresh waters like rivers and lakes etc., and in estuaries far above the tidal influences. It is most common in Uttar Pradesh, West Bengal, Bihar, Orissa and Tamil Nadu. Commonly known as Oran.

FIG. - I. - <u>Mugil corsula</u> (Hamilton)

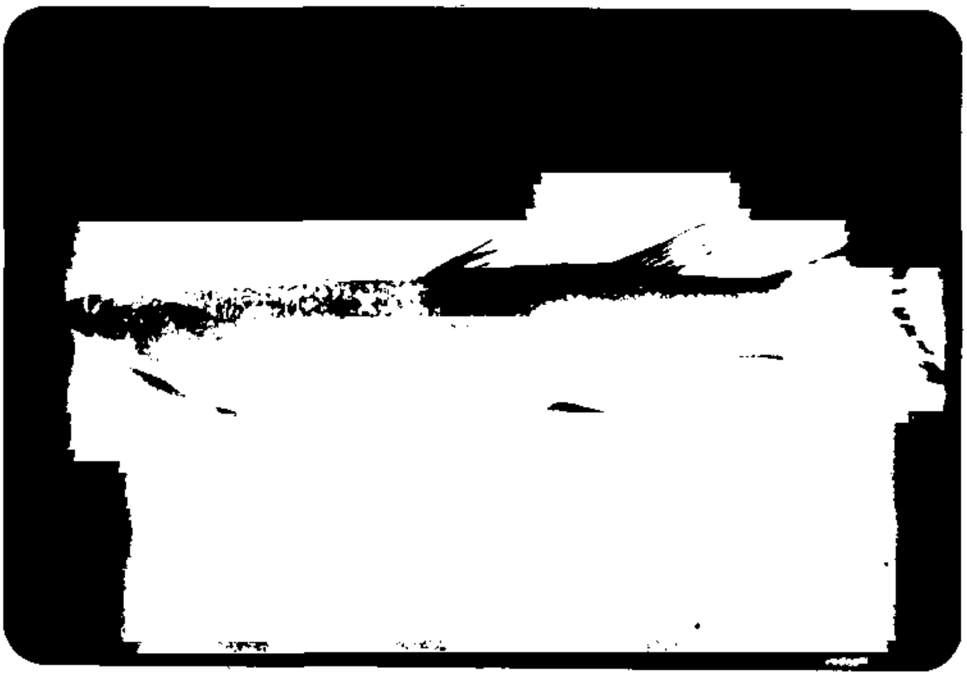


Fig. 1

CHAPTER - I

MORPHOMETRIC STUDIES

Knowledge of morphometric characters is very essential in fish taxonomy. The study of various morphometric characters in relation to each other is one of the most fascinating subject of biology, which gives a great clue of different changes occurring in the body parts and relating to the correlation of the growth rate of different body parts to a specific morphometric character in any particular environment. These growth rates may be directly or inversely propotional to each other.

Radhakrishnan (1957) elucidated that the separation of stocks or races of commercially important fishes is of great importance in fishery investigations. Slight but significant changes occur in the morphometric measurements between the fishes of different stocks, races or populations. Therefore, morphometric analyses have been employed in the study of races or population of fishes and in the study of the relative growth of body measurements.

It is essential to determine first of all, whether the samples handled in the course of investigation belonged to a single homogenous population or not. In the present work, samples were collected from a single environment i.e., river Jamuna. The variations in the morphometric characters are due to the modificational effect of environment or due to different hormonal activity of the fish as well as due to different genetic make-up.

Several workers have studied the biology of grey mullets (Hora, 1939; Pakrasi and Alikunhi, 1952; Pillay, 1954; Sarojini, 1957 and 1958; Ranganathan and Natarajan, 1969). Few of them have described morphometric character, but in brief. Various aspects of morphological characteristic of other fish species from the freshwaters have been investigated in detail (Pillay, 1957; Krumholz and Cavanah, 1968; Chatterji et al. 1977a; Islam and Al-Nasiri, 1978). Chatterji et al. (1977a) have stated that different races and populations show differences in body measurement.

Sexual dimorphism in various body measurements of fish has been reported by many workers (Tandon, 1962; Tariq, 1977). Tariq (1977) has reported that Labeo calbasu and Cirrhina reba showed a significant sexual dimorphism in various body measurements and these differences were more significant in the characters associated with length than the width. Such differences between the two sexes may be due to the hormonal activity of the fish as well as due to different genetic make-up (Krumholz and Cavanah, 1968).

Ranganathan and Natarajan (1969) recorded the correlation between total length and few body measurements of M. corsula collected from two different impoundments, Krishnagiri and Sathanur reservoirs, of Tamil Nadu. But unfortunately no comprehensive study on morphometrical correlation between the two sexes of M. corsula collected from single environment has so far been done. The present study, therefore, aims to ascertaining growth of body parts in relation to total length of a most common fish species, namely Mugil corsula (Ham.), found in river Jamuna. An attempt has also been made to distinguish males and females of M.corsula on the basis of morphometric characters.

More recently, the fishery biologist have often used the growth of body parts (morphometric character) in relation to total length of fish for the rational exploitation, growth pattern and overall well being of the existing fish stocks for better management practices (Lagler, 1956). M. corsula showed slight but significant sexual dimorphism in their morphometric characters in relation to total length. The differences and relationship between various body characters to a particular character of male and female specimen can not be judged easily, hence statistical methods are employed to test the significant differences occurred in body parts of two sexes.

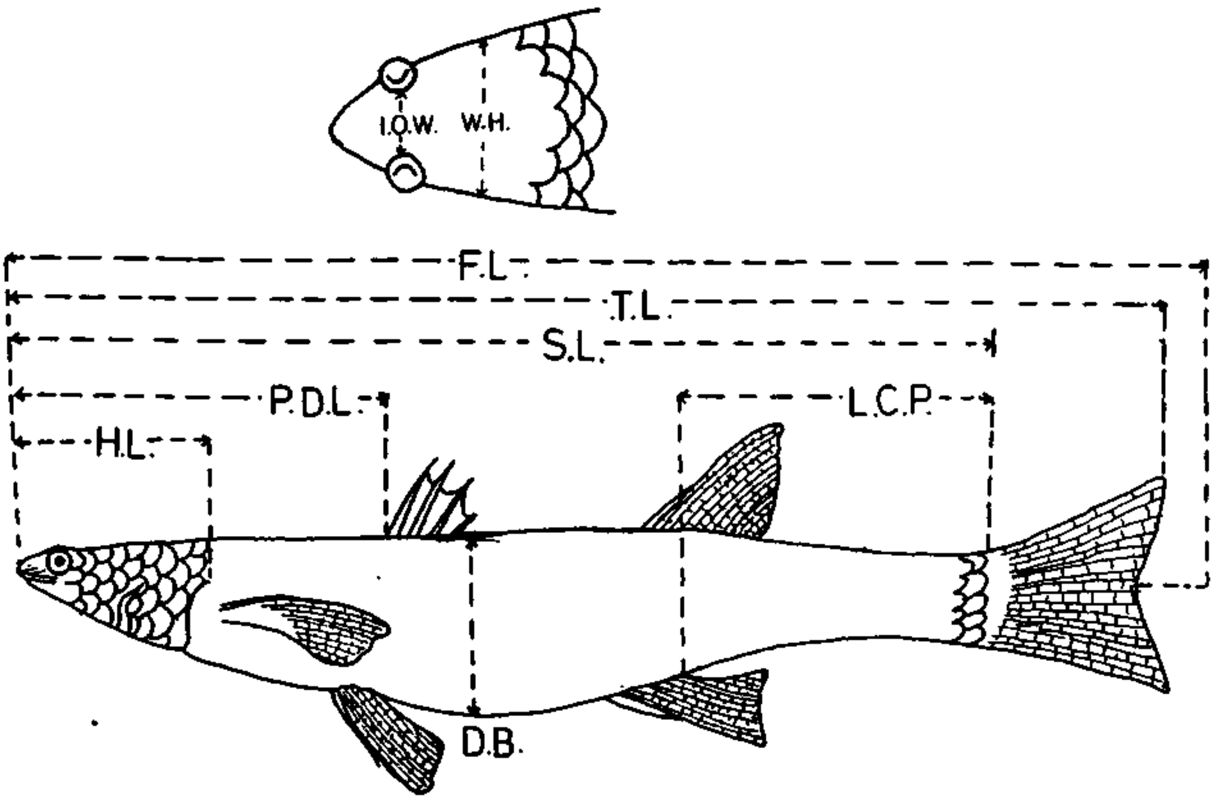


Fig. 2 Measurements of Mugil corsula used in racial study.

D.B.- Depth of body
F.L.- Forked length
H.L.- Head length
I.O.W. - Inter orbital width
L.C.P.- Length of caudal peduncle

P.D.L.- Pre-dorsal length
S.L. - Standard length
T.L. - Total length
W.H. - Width of head

Fin formula - $D_1$4/0; $D_2$1/8; P.1/13; V.1/6; A.3/9; C.15; L.l.55 $\frac{8}{9}$

MATERIALS AND METHODS

Samples for the morphometric study were collected from river Jamuna, at monthly intervals over a period of seven months from July 1985 to February 1986.

Specimens were brought to the laboratory and processed promptly. Processing included measurements of different morphometric character, and weight of body and gut.

Measurements of the following morphometric characters were taken into consideration to represent the relationship with total length:-

Total Length (T.L.) = is measured from the tip of snout to the tip of caudal fin.

Standard Length (S.L.) = is measured from the tip of snout to the base of caudal fin.

Forked Length (F.L.) = is measured from anterior most extremity to the notch in forked caudal fin.

Depth of Body (D.B.) = is measured along the vertical line at its deepest part.

Head Length (H.L.) = is measured from the tip of snout to the posterior most bony extremity of opercle.

Width of the Head (W.H.) = is measured along the broadest part of the head.

Inter-orbital Width (I.O.W.) = It is measured along the dorsal surface between the eyes.

Length of Caudal Peduncle (L.C.P.) = is measured from posterior base of anal fin to the base of caudal fin.
Pre-dorsal Length (P.D.L.) = is measured from the tip of snout to the origin of dorsal fin.
Gut Length (G.L.) = is measured from the oesophagus upto the anus.

After wiping off the moisture from the surface of the body, fishes were weighed on a balance and body measurements were taken to the nearest centimeter on a measuring board. For measuring gut length, all the fishes were dissected and guts were taken out. After removing all fats and raw material, length of the alimentary canal was measured upto the nearest cm.

Fishes were sexed, and for the identification of males and females gonads were studied under the microscope. The relationship between the dimension of external parts of fish and its total length was determined from the measurements of over 147 specimen, having 83 males and 64 females.

The total length of each specimen was used as a basis of reference for all other measurements (Carlandar and Smith, 1945; Hile, 1948). The regression of various body characters of different specimen against total length were compared by using the covariance technique (Mather, 1964). For computing the growth of body parts in relation to total length of the fish, the rectilinear regression was used, because the use of regression of original measurements rather than ratios is time saving, easier to interpret and less likely to lead to confusing or doubtful conclusions as stated by Maar (1955). In the present attempt, a linear regression of various body proportions against total length were fitted by the least square method. The measurements of all the characters were expressed as percentage of total length. The regression equation is represented as:

$Y = a + bx$; where

Y = Length of body parts of the fish (the dependent variable),

X = Total length of fish (the independent variable),

a = intercept, and

b = regression coefficient.

In order to assess closeness of relationship, that might exist in different cases, the values of regression and correlation coefficient (r) for all the morphometric characters were also computed.

RESULTS AND DISCUSSION

To facilitate the comparison of data the mathematical relationship between total length and body measurements was carried out. The regression analysis of different body measurements on total length and their significance has been tabulated in Table 1 and 2. The equation for the regression line, Y = a + bx, was used to express the relationship between the two sexes (Table 1). The mean relative measurements of different morphometric characters expressed as the percentage of total length (Table 1). Research workers very often use the standard length of fishes in their studies. Sarojini (1958) has used standard length of the *Mugil cunnesius* as the standard linear measurement instead of the total length, as the caudal fins were found damaged in most of the fish. Pillai (1983) made the biometry analysis in relation to standard length for *Otolithes ruber*. In the present study, total length is used as the standard linear measurement. Total length is more readily accepted and understood by everyone. Moreover, Pillay (1954) got some confusion in measuring standard length, as the base of the caudal fin in mullets is covered by scales and the end of the lateral line or the tip of the hypurals can not be located easily.

In the present study, various morphometric measurements of *Mugil cersula* are plotted against total length resulting in straight lines indicating linear relationship in each case (Figs. 3 to 8). The linear relationship showed that with the increase in total length of the fish there was corresponding increase in the length of body measurements. Ranganathan and Natarajan (1969) explained the relationship between total length and measurements of other body parts, namely standard length.

body height and girth of Mugil corsula collected from two reservoirs of Tamil Nadu. In all cases, they obtained a linear relationship. In our case, positive values of correlation coefficient (Table 2) indicated that all the morphometric parameters, taken into consideration, showed a gradual increase with increase in total length of the fish (Figs. 3 to 8). As it is evident from the figures, the gut length has the maximum rate of growth. Among other parameters, forked length and standard length increased at maximum rate with unit runs of total length, whereas inter-orbital width has the minimum rate of increase in each case. Pillay (1954) has reported that the measurements of different body parts of Mugil tade in the sea off Junput and in the river Matlah, in relation to total length, showed a straight line relationship with the standard length having the maximum rate of growth and the depth through orbit, the minimum. Sarojini (1958) elucidated the above observations for Mugil cunnesius in the same areas. Islam and Al-Nasiri (1978) analysed the observed data of Liza abu (Heckel) statistically in order to obtain mathematical relationship between the measurements of body parts (dependent variable) and that of the body length (independent variable). A straight line linear relationship was observed in each case. Similar observations have been reported by Pillai (1983) in Otolithes ruber.

In the present study, the regression of body measurements on total length showed almost a linear relationship in all the cases which suggested that the growth of fish was isometric. However, some workers have reported that the regression of one character on the other showed a non-linear relationship (Godsil, 1948; Marr, 1955; Halt, 1960). They observed that the ratio between various body parts with increasing length of different stages of life may not be having constant relative growth. Khan (1972) has reported such linear relationship between body parts to total length within a certain range of independent deviation, and observed that the growth rate of _Labeo rohita_, only above 50 mm, was isometric. Similar cases have also been reported by Chatterji _et al_. (1977a) in the case of _Labeo bata_. They found an isometric growth rate above 190 mm. Tariq (1977) has also found that the relative growth of _Labeo calbasu_ and _Cirrhina reba_ was not constant throughout the life. The ratios between the different body parts differed at different stages of life with increasing length. But in both the species, the regression of body measurements on total length has been found to be almost a linear relationship.

While comparing the different characters from the fishes of two environments, Khan (1972) noticed a significant difference in _Labeo rohita_. He found that the fishes of pond increased in length more rapidly than the width, whereas the fishes of river increased in width more rapidly than their length. It was further noticed by Chatterji _et al_. (1977a), while comparing the morphometric characters of _Labeo bata_ from two different environments, that the growth of Labeo bata showed similar pattern as it is reported by Khan (1972) in L. rohita. The significant differences in all the characters between the two environments suggested that these fishes belonged to two different stocks. These variations in the morphometric characters of the fishes of two populations are due to modificational effects of environment or due to genetic make-up (Krumholz and Cavanah, 1968). They concluded that the fishes of pond adapted from the very beginning to confined water while the riverine fishes enjoyed a wide distribution. Another reason for the differences was given that most of the fishes stocked in ponds were induced spawned, while the fishes of rivers were obviously naturally spawned. Sarojini (1957) compared the samples of Mugil parsia from Junput, Diamond Harbour and Port Caning. She observed that the stocks in these three areas did not differ significantly one another and were derived from a homogenous population. Pillay (1954) has also found that Mugil tade occurring in these three areas, belonged to homogenous populations.

The observed data of Mugil corsula which were collected from a single environment, when analysed statistically in order to obtain mathematical relationship between the measurements of the total lengths (independent variable) have showed a linear relationship in all the cases. While comparing the different characters of male and female significant differences were found in their measurements (Table, 2 and Figs. 4,5,7 and 8). The observed values suggest that the relative growth of both sexes was not same in all the morphometric characters and the fishes exhibited significant sexual dimorphism. The value of correlation coefficient (r) for width of the head is higher in the case of males than in the females. The values for pre-dorsal length and depth of the body are greater in females than in the males (Table, 2; Figs., 4,5,7 and 8). Here it can be concluded that the significant differences occurred in the characters associated with length as well as width of the body parts. Such differences between the two sexes may be due to different hormonal activity of the fish as well as due to different genetic effects (Krumholz and Cavanah, 1968). Sexual dimorphism in various body measurements have also been reported by many workers. Tandon (1962) has reported different ratios between various body parts and total length of male and female experimental fishes. Similarly Tariq (1977) observed significant sexual dimorphism in various body parts of Labeo calbasu and Cirrhina reba. He observed that all the measurements in males were higher than in the females. The differences were more significant in the characters associated with length than width. Talwar (1961) concluded that the significant differences in the sample of Halfbeak from Rameswaram with regard to the regression coefficient of the four morphometric characters did not reveal any sexual heterogeneity. The analysis indicates that the samples were derived from a homogenous population. On the contrary, Khan (1972) and Chatterji *et al*. (1977a) have reported in *L. rohita* and *L. bata* respectively that none of the body characters showed any sexual difference in any of the two environments. The relative growth of both the sexes was found to be constant and same.

Table - II Statistics of Regression of Different Body Measurement on Total Length

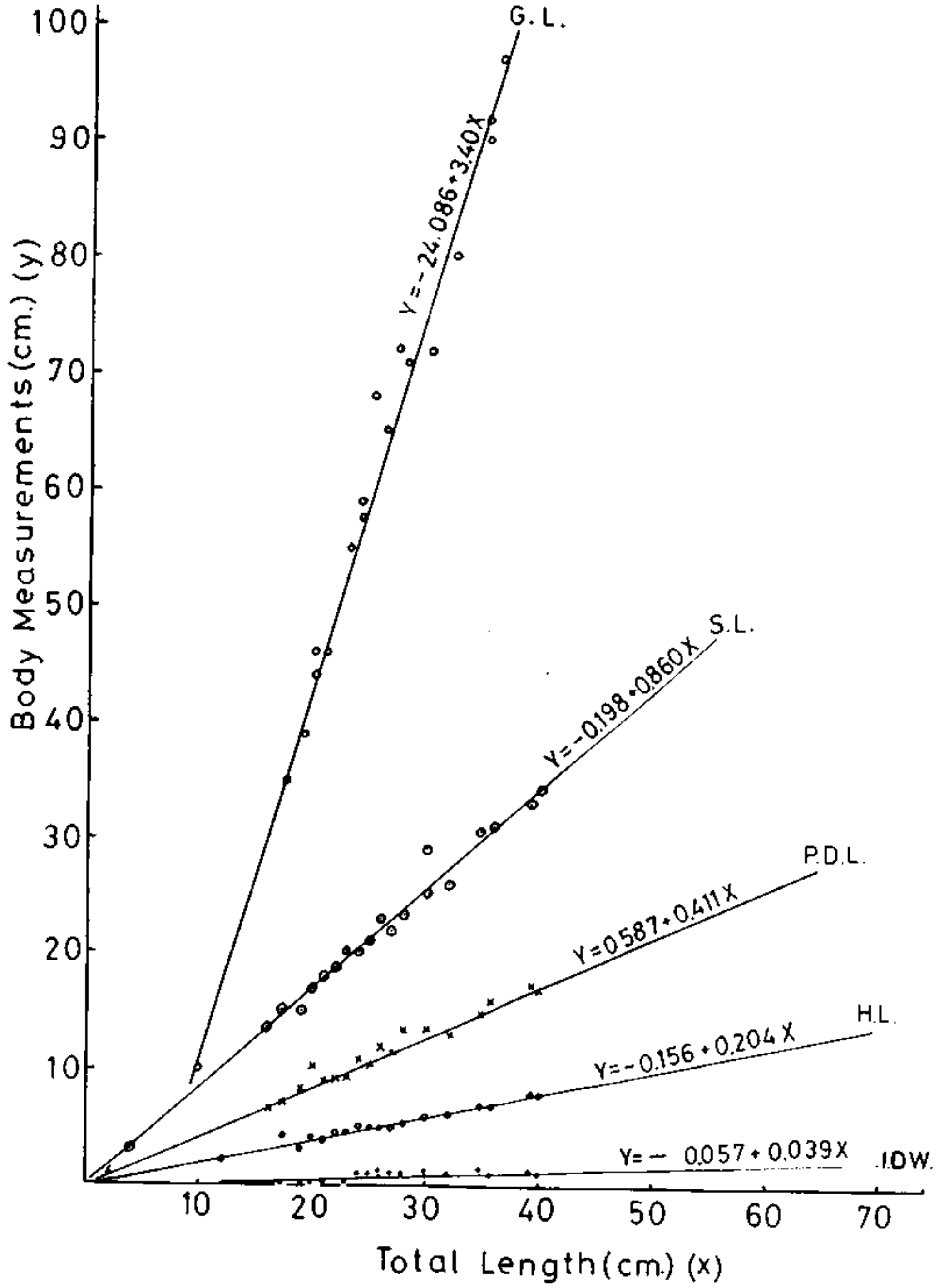
CHARACTERS	Regression coefficient (b)	S.S. due to the regression (B)	Residual S.S.	Correlation coefficient (r)	Significance level
			COMBINED		
Standard length	0.860	1272.619	154.690	0.944	$P < 0.001$
Forked length	0.936	1506.566	51.824	0.983	$P < 0.001$
Depth of the body	0.167	48.024	27.486	0.798	$P < 0.001$
Head length	0.204	71.814	8.351	0.948	$P < 0.001$
Width of the head	0.123	26.046	22.384	0.733	$P < 0.001$
Inter-orbital width	0.039	2.634	1.102	0.842	$P < 0.001$
Length of caudal peduncle	0.186	59.538	19.862	0.866	$P < 0.001$
Pre-dorsal length	0.411	290.613	110.330	0.851	$P < 0.001$
Gut length	3.409	1998.362	2535.423	0.942	$P < 0.001$
			MALE		
Standard length	0.940	318.537	-8.611	0.946	$P < 0.001$
Forked length	0.988	403.400	5.841	0.992	$P < 0.001$
Depth of the body	0.139	8.007	13.343	0.613	$P < 0.001$
Head length	0.177	12.955	4.165	0.870	$P < 0.001$
Width of the head	0.224	20.800	4.474	0.908	$P < 0.001$
Inter-orbital width	0.050	1.044	0.339	0.873	$P < 0.001$
Length of caudal peduncle	0.208	17.956	8.424	0.826	$P < 0.001$
Pre-dorsal length	0.194	15.556	67.925	0.429	$P < 0.001$
Gut length	4.230	7396.155	1002.774	0.938	$P < 0.001$
			FEMALE		
Standard length	0.848	720.359	119.001	0.926	$P < 0.001$
Forked length	0.920	847.650	45.062	0.974	$P < 0.001$
Depth of the body	0.171	29.383	13.747	0.827	$P < 0.001$
Head length	0.202	41.030	3.661	0.960	$P < 0.001$
Width of the head	0.084	7.110	12.203	0.608	$P < 0.001$
Inter-orbital width	0.037	1.387	0.692	0.822	$P < 0.001$
Length of caudal peduncle	0.181	32.820	11.190	0.864	$P < 0.001$
Pre-dorsal length	0.466	217.566	16.092	0.965	$P < 0.001$
Gut length	3.446	11952.813	719.970	0.968	$P < 0.001$

STATISTICAL ANALYSIS

CHARACTERS	Mean total length cm $(\bar{X})$	Mean length of body measurements cm $(\bar{Y})$	Regression equation $Y = a+bx$	D.F. n-2	Percent of total length $\frac{Y}{X} \times 100$
			COMBINED		
Standard length	24.69	21.050	Y=-0.198 + 0.860x	145	85.25%
Forked length	24.69	23.860	Y= 0.751 + 0.936x	145	96.63%
Depth of the body	24.69	4.655	Y= 0.532 + 0.167x	145	18.85%
Head length	24.69	4.880	Y=-0.156 + 0.204x	145	19.76%
Width of the head	24.69	2.976	Y=-0.064 + 0.123x	145	12.05%
Inter-orbital width	24.69	0.905	Y=-0.057 + 0.039x	145	3.66%
Length of the caudal peduncle	24.69	5.219	Y= 0.627 + 0.186x	145	21.13%
Pre-dorsal length	24.69	10.741	Y= 0.587 + 0.411x	145	43.49%
Gut length	24.69	60.089	Y=-24.086+ 3.409x	145	243.30%
			MALE		
Standard length	23.43	19.848	Y=-2.176 + 0.940x	81	84.10%
Forked length	23.43	22.701	Y=-0.448 + 0.988x	81	96.80%
Depth of the body	23.43	4.414	Y= 1.157 + 0.139x	81	18.83%
Head length	23.43	4.607	Y= 0.458 + 0.177x	81	19.66%
Width of the head	23.43	2.831	Y=-2.433 + 0.224x	81	12.08%
Inter-orbital width	23.43	0.867	Y=-0.317 + 0.050x	81	3.70%
Length of caudal peduncle	23.43	5.002	Y= 0.108 + 0.208x	81	21.34%
Pre-dorsal length	23.43	10.078	Y= 5.532 + 0.194x	81	43.01%
Gut length	23.43	57.330	Y=-41.8 + 4.230x	81	244.60%
			FEMALE		
Standard length	26.33	22.620	Y= 0.29 + 0.848x	62	85.90%
Forked length	26.33	25.360	Y= 1.137 + 0.920x	62	96.30%
Depth of the body	26.33	4.967	Y= 0.445 + 0.171x	62	18.86%
Head length	26.33	5.268	Y=-0.076 + 0.202x	62	20.00%
Width of the head	26.33	3.160	Y= 0.933 + 0.084x	62	12.00%
Inter-orbital width	26.33	0.954	Y=-0.032 + 0.037x	62	3.62%
Length of caudal peduncle	26.33	5.501	Y= 0.73 + 0.181x	62	20.80%
Pre-dorsal length	26.33	11.600	Y=-0.68 + 0.466x	62	44.05%
Gut length	26.33	63.650	Y=-27.087+ 3.446x	62	241.70%

REGRESSION LINES SHOWING RELATIONSHIP OF VARIOUS MEASUREMENTS TO TOTAL LENGTH

FIG. 3 AND 6 - Combined Fishes
FIG. 4 AND 7 - Male Fishes
FIG. 5 AND 8 - Female Fishes



G.L.
Y=-24.086+3.40X
S.L.
Y=-0.198+0.860X
P.D.L.
Y=0.587+0.411X
H.L.
Y=-0.156+0.204X
Y=- 0.057+0.039X
I.D.W.
Body Measurements (cm.) (y)
Total Length (cm.) (x)
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70

Fig. 3

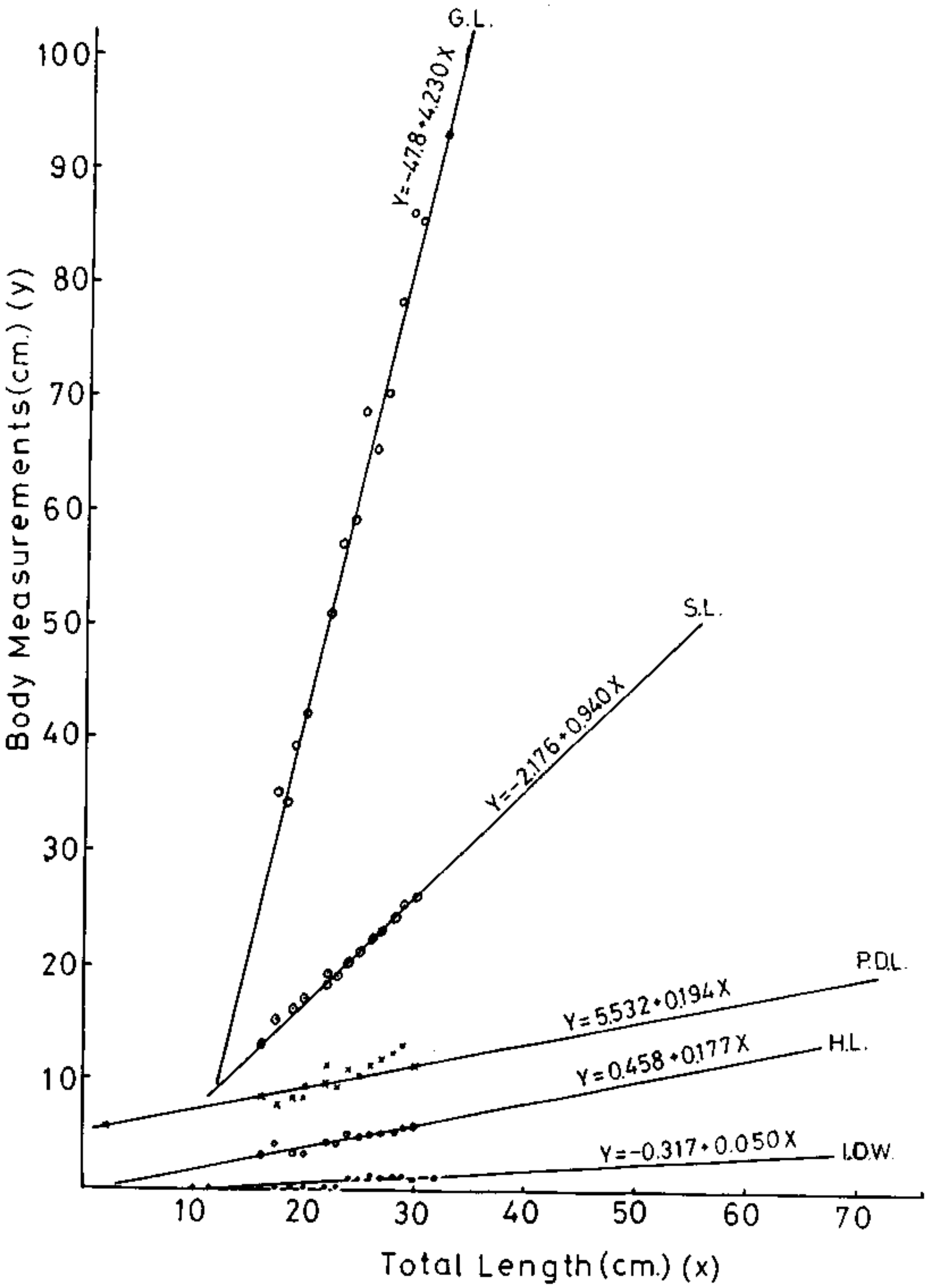
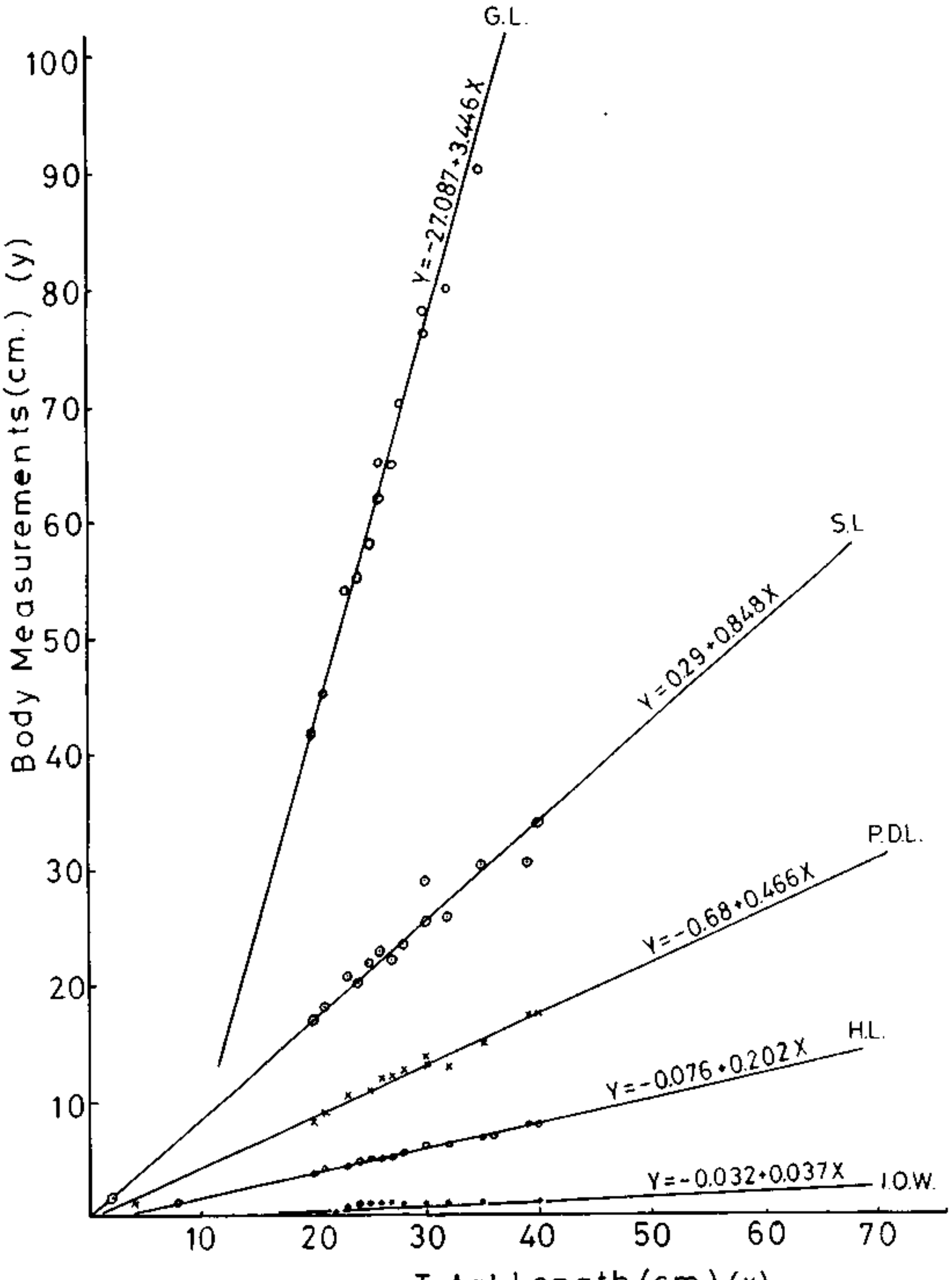

G.L.
Y=-47.8+4.230X
S.L.
Y=-2.176+0.940X
P.D.L.
Y=5.532+0.194X
H.L.
Y=0.458+0.177X
I.O.W.
Y=-0.317+0.050X
Body Measurements (cm.) (y)
Total Length (cm.) (x)
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70

Fig. 4



G.L.
S.L
P.D.L.
H.L.
I.O.W.
Y=-27.087+3.446X
Y=0.29+0.848X
Y=-0.68+0.466X
Y=-0.076+0.202X
Y=-0.032+0.037X
Body Measurements (cm.) (y)
Total Length (cm.) (x)
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70

Fig. 5

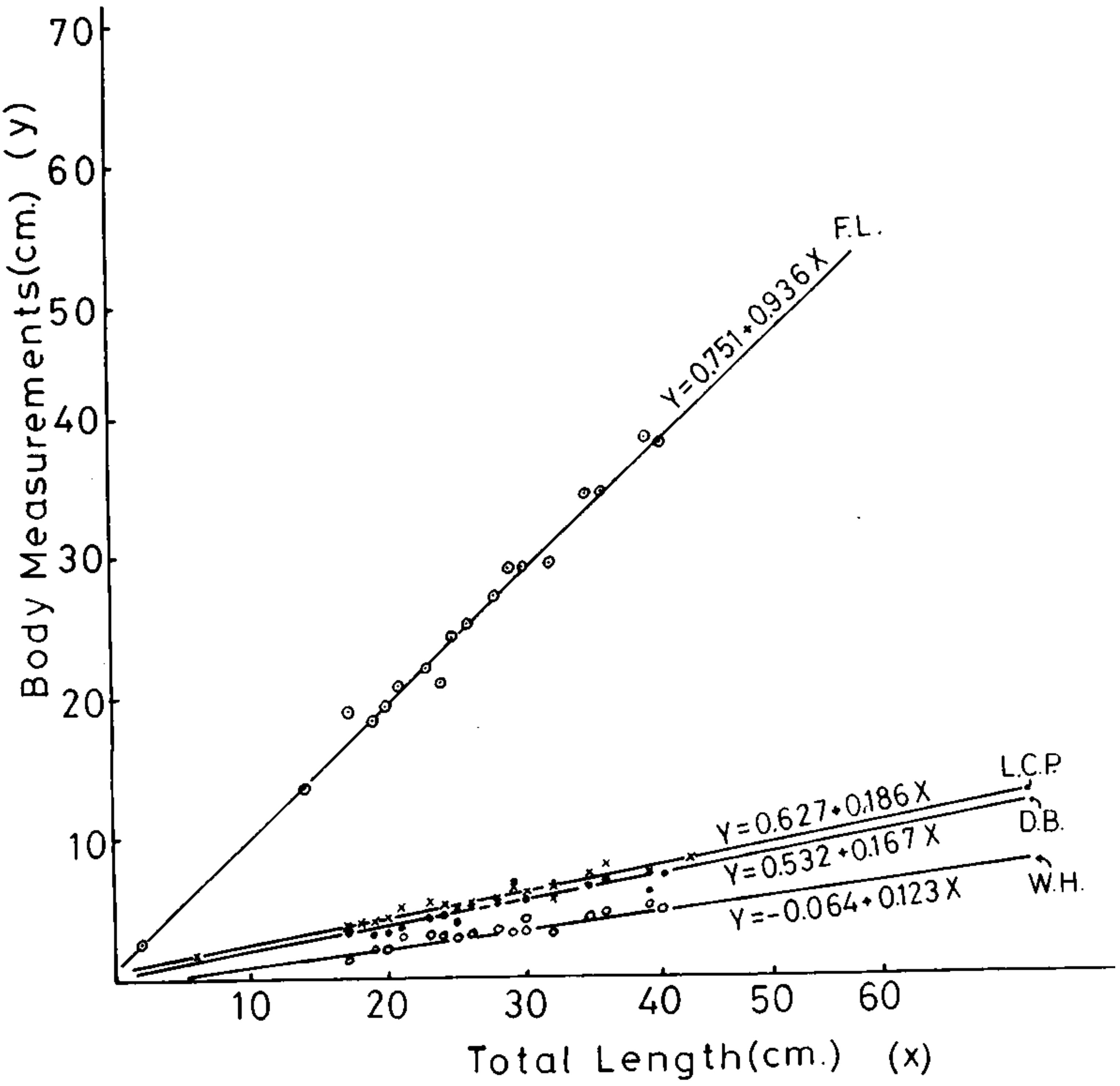
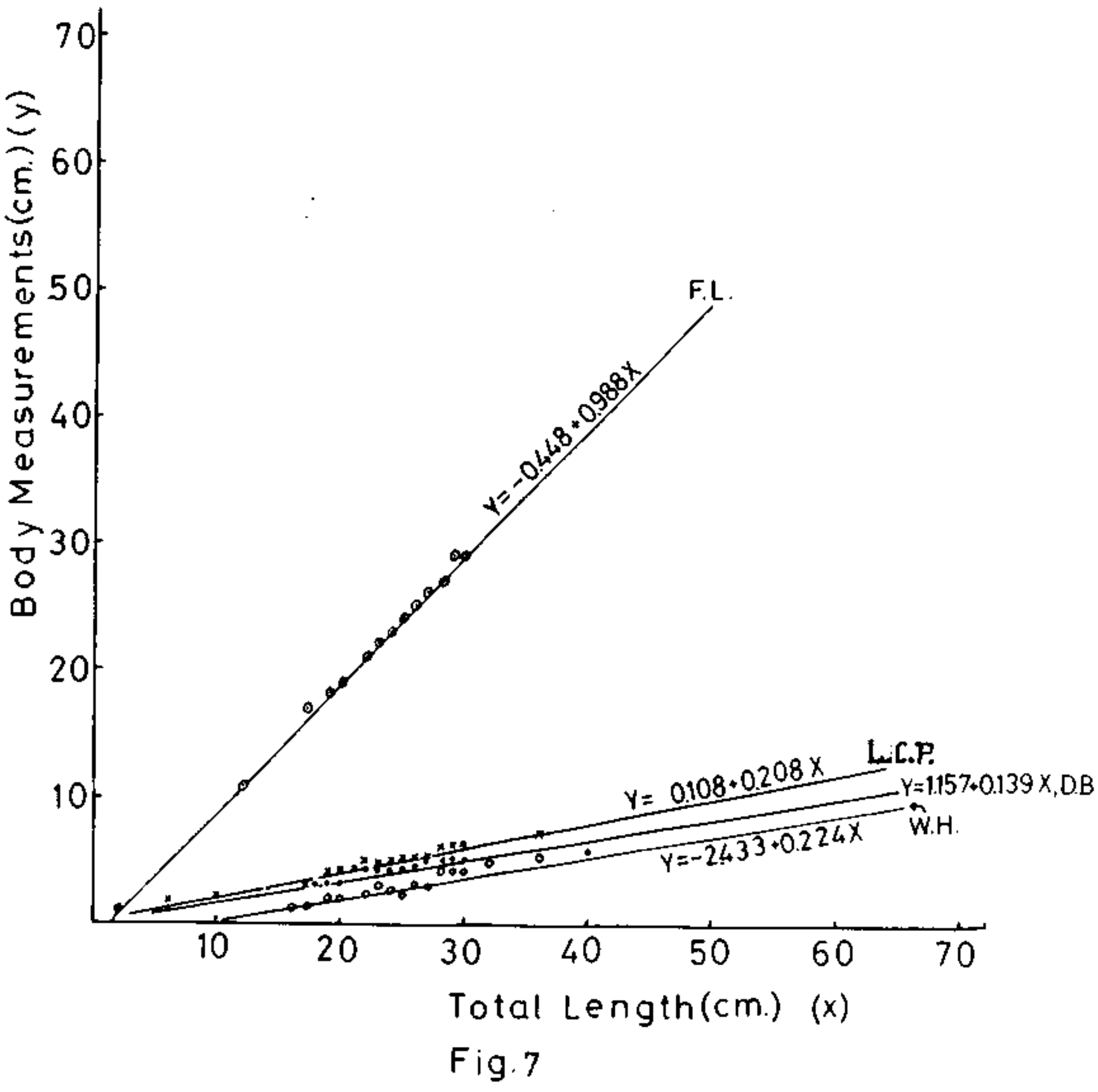

Body Measurements(cm.) (y)
70
60
50
40
30
20
10
10
20
30
40
50
60
Total Length(cm.) (x)
F.L.
Y=0.751+0.936 X
L.C.P.
Y=0.627+0.186 X
D.B.
Y=0.532+0.167 X
W.H.
Y=-0.064+0.123 X

Fig.6



Body Measurements(cm.) (y)
70
60
50
40
30
20
10
10
20
30
40
50
60
70
Total Length(cm.) (x)
F.L.
Y=-0.448+0.988X
L.C.P.
Y= 0.108+0.208X
Y=1.157+0.139X, D.B
W.H.
Y=-2.433+0.224X

Fig. 7

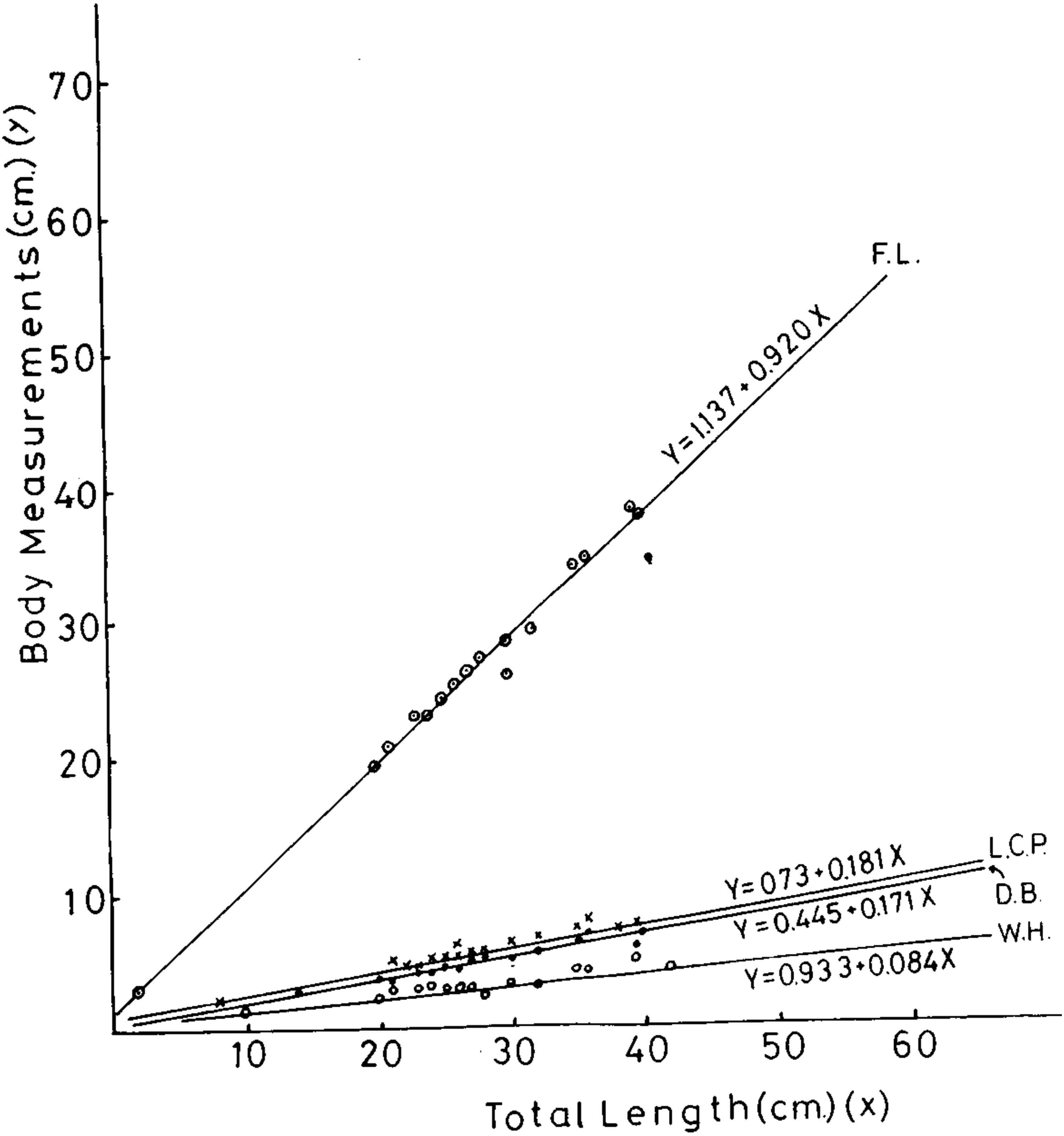

70
60
50
40
30
20
10
Body Measurements (cm.) (Y)
10
20
30
40
50
60
Total Length (cm.) (x)
F.L.
Y=1.137+0.920X
L.C.P.
Y=0.73+0.181X
D.B.
Y=0.445+0.171X
W.H.
Y=0.933+0.084X

Fig. 8

CHAPTER - II

FOOD AND FEEDING HABITS

Animal likes to survive first (self preservation) then it thinks about its race preservation. For self preservation feeding provides an important function, while for race preservation breeding is important. Food and feeding habit is an important function of all living organisms. It is life sustaining activity. It provides life, growth, energy requirements for reproduction and for other life activities. Therefore, it is given first priority by all the living organism.

Knowledge of feeding habit of fishes is very useful in polyculture. Rational pond cultivation of fishes is inconceivable without a knowledge of basic problems of the nutrition of fishes. Acclimatization projects, concerned with the planting of water masses, should only be carried out after a detailed study of feeding inter-relationships and food supply of the fishes in the water mass. The results so obtained may be of some use for the management of fisheries in the rivers, ponds etc. .

The study of food and feeding habit of fishes is as old as fishery science. It is an important aspect of biology of fishes. The importance of studies on food and feeding habit of fishes in fishery management investigation is well known and considerable attention is being paid at the moment to this problem in India. Knowledge of different feeding habits of fishes, besides being advantageous in the proper exploitation of resources, will have an applied value in fish culture practices specially in composite fish farming. For this, one should know the zonal distribution of the fishes selected for aquaculture practices. The fish, as grows there is a change in their diet requirements, so the pisciculturist should know the diet on which a particular fish switch over after cetain period of time, and can avoid the competition for food in last stages.

From India, several publications on food and feeding habits of freshwater fishes have been reported:Labeo rohita (Das and Moitra, 1955b; Vasisht, 1960; Khan, 1972), Cirrhina mrigala (Chakrabarty and Singh, 1963; Khan, 1972); Catla catla (Natarajan and Jhingran, 1963; Khan, 1972); Ophicephalus punctatus, Barbus stigma and Callichrous bimaculatus (Qayyum and Qasim, 1964a,b and c); Labeo fimbriatus (Bhatnagar and Karamchandani, 1970), Labeo calbasu and Labeo gonius (Chatterji et al. 1977b).

Several contributions have also been made on food and feeding of mullets by Pillay (1950, 1953), Sarojini (1954), Luther (1962), and Prasadan (1970). But, in spite of considerable importance of Mugil corsula as a food fish, nothing is known about the diet of this species either in rivers or in lakes.

Hora (1939) pointed out the importance of an anatomical study of Mugil corsula and elucidated the structural adaptation and modifications that are brought about by its surface feeding habit. Bhimachar (1945) reported the correlation between the surface living habit and structure of brain of Mugil corsula. To describe the surface living habit of Mugil corsula, Hora (1939) states 'Mugil corsula has the remarkable habit of swimming with its eyes above the surface of water". While describing this species, Day (1889) observed "These fish swim with their eyes just above the surface of water, giving the appearance of a number of tadpoles". Immediately as they are disturbed they dive down with great rapidity.

Except preliminary observation made by Hora (1939) and Bhimachar (1945) so far no comprehensive work, especially on food and feeding habits of Mugil corsula, has been attempted. Their diverse observations have indicated the need for examining a little more closely the food and feeding habits of Mugil corsula to ascertain the diversity. Hence, the present study has been undertaken to elucidate the food and feeding habits of the species which lives at the surface of water in culture ponds, reservoirs and rivers of the gangetic provinces.

MATERIALS AND METHODS

Samples which formed the basis of this investigation were collected directly from the river Jamuna with the help of cast net and gill net.

Unlike as in the case of terrestrial animals, it is not usually possible to observe the food and feeding habit of a fish in its natural surrounding and thus determine accurately what it feeds on. So, obviously the best method of ascertaining its food is the examination of its gut content. Examination of gut content is the only possible method to infer about the feeding habit of aquatic animals like fish, in whose case it is not easy to directly observe them feeding in their natural habitat.

After collecting the samples of Mugil corsula from the natural habitat, each fish was measured up to nearest centimeter from the tip of snout to the long ray of caudal fin, weighed nearest to 1 gm and sexed. State of maturation was determined following the scheme of classification used for Ophicephalus punctatus (Qayyum and Qasim, 1964a) and carps (Khan, 1972 and

Chatterji, 1976). Fish were generally cut open and viscera were taken out carefully starting from the oesophagus to the last part of intestine. After noting the length of alimentary tract on fish measuring board, weight of alimentary tract on a sensitive balance was taken, and preserved in 5% formaline for further processing in the laboratory.

The study of food and feeding habits was taken up as a part of comprehensive study of biology of fish, involving a detailed study of samples. It was not possible to examine the gut contents in fresh condition in the field, which are in all cases far off from laboratory.

Five portions of gut were taken from different regions of the gut and all food items present in it were taken out and washed thoroughly in a petri-dish containing adequate quantity of water. It was then thoroughly mixed. A sample of 0.2 ml was taken out on a Sedgewick Rafter slide with the help of a dropper, and examined under the microscope.

Gut contents analysis was made by number method as described by Hynes (1950), Pillay (1952), Khan (1972) and Chatterjie (1976). It is based on counting the number of food items. According to them, "the number of each food item is counted and expressed as percentage of all total number of food items present in the gut". Various food organisms were identified up to generic level, counted and their relative abundance was determined as percentage of total food material present in the gut. The process was repeated again and again and a mean of each food item was determined.

Presence of large quantities of decayed organic matter, sand and mud made this work extremely difficult as they could not easily be separated from the algae and diatoms. Organic matter consisted mainly of decayed slimy mass of unidentified plant matter. As it was not possible to count the fragments of vegetable matter in a finely divided state, Pearse's method of eye estimation (Pearse, 1915) was found to be only feasible means of determining the decayed organic matter. In the present work, percentages of decayed organic matter, sand and mud grains were determined by eye estimation following the scheme of Pillay (1952). The number of fishes with empty guts were also noted in each month and expressed as the percentage of total number of fishes examined in that month. The intensity of feeding or the rate of feeding was studied by determining the gastro-somatic index (gut-weight expressed as percentage of body weight).

RESULTS AND DISCUSSION

The morphological features of the alimentary canal of the fish provide a clue to its food and feeding habits. The alimentary tract of *Mugil corsula* is an extremely coiled organ

(Fig. 9). It lies below the air bladder which extends throughout the coelomic cavity. The regions which could be distinguished in the alimentary tract are the mouth, the oesophagus, the stomach, the intestine, and the rectum (Fig. 9-A). The mouth, buccal cavity pharynx, oesophagus and stomach can be easily recognised, but the exact boundaries of the other regions are not clearly marked out.

The alimentary canal of the fishes are generally adapted to their feeding habits (Al-Hussaini, 1946; and Khanna, 1961). Khanna (1961) has studied the alimentary tracts of some teleostean fish wherein the different structural modifications met with in the various species, were correlated with the food and feeding habits. Mugil corsula is predominantly mud feeder and characterised by the presence of "V"- shaped mouth, slightly inferior in position and the gape is moderate. The mouth leads into the triangular dorso-ventrally compressed buccal cavity. Upper jaw over hung by the snout and is longer than the lower one. Upper lip is thick and notched for receiving the tubercle of the lower lip, when the mouth is closed. Both jaws are having a row of very small and minute teeth (Fig. 9-B). Mugil corsula had a long narrow oesophagus followed by the stomach which is somewhat specialized in this species. It consists of a proximal narrow part and a distal muscular round sac (Gizzard). The proximal part of the stomach is produced behind into two finger like processes, pyloric caecae, which open into the muscualr sac. This is followed by the lengthy intestine which is wider in its anterior section and narrows down posteriorly. Two well developed finger like pyloric caecae open into the intestine after the pylorus. The last part of the intestine may be regarded as the rectum and opens into the exterior as anus. According to Al-Hussaini (1946) and Khanna (1961) observations on the comparative study of the alimentary canal of some freshwater fishes has revealed many variations that are undoubtedly correlated with differences in their food habits. The length of the gut of predatory or carnivorous fishes are generally shorter, the omnivorous ones have comparatively longer length, while herbivorous and planktivorous species are characterised by the possession of still longer length. It seems that the kind of the food taken by a fish determines the length of the gut. A muscular gizzard appears to be an adaptation for their diet. It is helpful in crushing the food. The food of these species includes large quantities of sand or mud obtained from the river bottom and the organic matter present in it is utilized by these fish for sustenance. I have also been able to corroborate this in *Mugil corsula*.

The study of organs of feeding and the structural modifications furnish the evidences that the fish is herbivorous, feeding mainly upon aquatic vegetation and plankton. The mouth, lips, buccal cavity, gill rakers and gut are well adapted for this mode of feeding (Fig. 9-A and B). Accounts of the diverse views expressed on the food of the grey mullets by various authors have been discussed in the work of Pillay (1953) and Sarojini (1957). Grey mullets have been described as plankton-feeder, herbivorous, omnivorous, slime feeder, foul feeder and bottom feeder etc. Gunther (1861 and 1880) first observed that the fish of this genus fed on organic substances mixed with sand or mud, an observation later corroborated by Hornell (1911). Hornell (1911), however, added that they feed voraciously on occasions upon shoals of small crustaceans. Jacot (1920) explained that the stomach contents of the adult fish consisted roughly of 40% sand and mineral matter, and remaining 60% vegetable and animal matter. He found that the juveniles of M. cephalus, like those of the allied M. curema, had an exclusive diet of crustaceans, mainly copepods. The findings of Hora(1939) and Pillay (1948) have all indicated that the mullets are herbivorous.

The findings of certain other workers suggest the possibility of the grey mullets being omnivorous. Kyle (1926) observed that mullets fed on the mud or detritus containing the remains of plant and animal bodies that have settled to the bottom, while Norman (1937) found that decomposed animal and vegetable matter contained in mud formed the food of mullets. Mookerjee et al. (1946) found mixed food in 10 specimen of M. belanak. Though algae formed 50% of the gut contents, the percentage of animal matter was as high as 40%. Devanesan and Chidambaram (1949) found that mullets fed on sea-weeds and planktonic organisms, generally larvae of bristle-worms (polychaetes) and larval molluscs. A different opinion on the food of mullets has been expressed by certain other workers. From a study of the gut content of 12 species of mullets from Madras, Chacko and Venkataraman (1945) inferred that they were chiefly plankton feeders, an inference which Jacob and Krishnamurthy (1948) have also corroborated. Moses (1941) included mullets among foul feeders as they feed on "odds and ends of decayed faecal matter".

A still different view has been held by some workers. Kesteven (1942) was unable to find any discrete identifiable material in the stomach of the Australian mullet, M. dobula and therefore, suggested that they may be bottom feeders making use of accumulations of detritus in lakes and estuaries, while in a later contribution Thomson (1951) has reported the presence of diatoms and other constituents of the flora and fauna in the gut content. In freshwaters, they were observed to depend on green algae, to some extent.

More contributions have since then been published in India containing further information on this subject. Bapat and Bal (1952) have stated that copepods constitute the main food of M. parsia in Bombay waters, which is supplemented by diatoms and organic matter taken along with mud. Chidambaram and

Kuriyan (1952) have concluded that the mullets, M. troschelii, M. waigiensis and M. seheli of the Gulf of Mannar are primarily plankton feeders, with occasional browsing habit at the bottom in the full grown mullets. Pillay (1953) has confirmed his earlier observations (Pillay, 1950) that the adults of M. tade feed at the bottom on decayed organic matter and live plants. Following observations of the present study have been undertaken to elucidate the bottom feeding habit of M. corsula.

FOOD COMPOSITION AND ITS VARIATIONS WITH SEASON:

Seasonal variations in the composition of gut content of M. corsula becomes quite apparent from Table III and presented graphically in Figures (10-12). The data indicate that phytoplankton form the main food throughout the year. The analysis showed that diatoms, green algae, blue green algae, desmids, algal spores and zygotes, macrovegetation, rotifers, copepods, cladocerans and their appendages along with the decayed organic matter together form its main food. Sand grains and mud appear to be taken in automatically along with the aforesaid food items associated with them, when the fish feeds on the bottom or littoral areas.

DECAYED ORGANIC MATTER

The percentage composition of each food item in the dietary of the fish during different months of the year is presented in

Table (III) and Figure (11-D). It is found that decayed organic matter forms the main part of the food throughout the year. This group mainly consisted of a slimy mass of unidentifiable plant matter in decayed condition and constituted about 27.4% of the stomach content, and thus ranked as the most important item of food. Its percentage fluctuated in every month, but it occurred regularly in guts of every fish throughout the year. During rainy season, in the months of July and August, there was an abundance of decayed organic matter forming 35% and 36.0% respectively. It appears that the rivers are loaded with organic matter during these months and their source is incoming water. Percentage of decayed organic matter was quite low during winter months. The occurrence and the quantities consumed in different months furnish the evidence that this environment always loaded with sufficient amount of silt containing considerable quantities of decayed organic matter. Sarojini (1954) has also investigated and reported such deposition of decayed organic matter, on which grey mullets (M. tade; M. parsia, and M. speigleri) have used to feed from several other areas of Bengal. She obtained fair quantities of this food material in their guts.

The gangetic system is noted for their enormous quantities of silt it washes down and along the margins of estuaries can be seen thick deposit of detritus. Pillay (1953) noted that the fish, Mugil tade, sucks in considerable quantities of this food item. He observed higher amount of decayed organic matter in the gut of *Mugil tade* collected from brackish water pond. The percentage of this matter was on the peak in June, July and August, and the period when minimum quantity eaten was November (Fig. 11-D). Luther (1962) studied the food habits of *Liza macrolepis* and *Mugil cephalus* and pointed out that these mullets, from the fingerling size onward, obtain their diet consisting mainly of decayed organic matter and foraminifera supplemented with fresh and decayed plant and animal matter from iliotrophic layers on the substratum of their habitat. Sreenivasan (1968) feels that the high organic matter of the bottom deposits may be directly used as food by these fishes. Khan and Siddiqui (1973) found predominent percentage of decayed organic matter in bottom feeder fish, *Cirrhina mrigala*. The presence of organic matter in the stomach of *Mugil corsula* also indicate its bottom feeding habit. The present finding are also supported by the reports of Chatterji *et al*. (1977b) for *Labeo gonius*.

In the present investigations, maximum quantity of this type of food occurred in July and August, and minimum in winter. An examination of the graph shows that when the percentage of algal food was high, decayed organic matter was very low. It was either due to the relative abundance of algae in the locality or due to selective feeding by the fish (this aspect of study will be taken up later on for Ph.D. work). However, the experimental data appears to show that the fish prefers either decaying or fresh algae whenever available, and when it is not available the fish subsits on decayed macrovegetation.

DIATOMS (Bacillariophyceae)

Diatoms on the whole formed about 21.7% of the gut contents of the fish. These were invariably found along with the sand grains and decayed organic matter indicating that they were consumed from the bottom zones. Mention has already been made by Sarojini (1954) about the presence of diatoms on the mud flats. Even planktonic diatoms are known to settle down to the bottom at certain times, and while feeding at the bottom the fish could have consumed these diatoms also. The present findings of diatoms in the guts of Mugil corsula also suggest that the fish has a browsing habit and consumed its food from the substratum of the river. Various forms of diatoms identified from the gut contents are displayed in Table III. This group forms principally as a regular item with a good percentage in each month. It is represented by 12 genera forming the chief food of the fish (Table III). Out of these Navicula; Nitzschia; Syndera; Diatoma and Melosira found in appreciable quantities throughout the year. The group formed the major part of the stomach content in increasing order from July to December. The percentage regressed in the month of January in comparison to December, when a large percentage of the fish were found to have the stomach well gorged. Figure 10-A shows samples of gut content containing high percentages of diatoms during December, and very low in July (8.7%).

GREEN ALGAE (Chlorophyceae)

The abundance of algae, either floating or forming a thick deposit at the bottom, has already been pointed out by Biswas (1927). These thick bluish green or blue black layers of fresh or decayed algae can often be seen adhering to grasses or other submerged plants along the margin of the ponds, lakes and rivers. These algae appear to be a favourite item of mullet food as they predominated in the gut contents of mullet, *Mugil tade* (Pillay, 1953). In the present study, the most predominant algae found in the gut contents, were green algae. The percentage composition of green algae constituted about 11.7% of bulk of the food. The most important genera were *Ankistrodesmus*; *Protococcus* and *Scenedesmus* occurring regularly in the gut of *M. corsula*. The less important genera were *Microspora*, *Spirogyra*, *Ulothrix*, *Zygnema*, *Actinastrum*, *Selenastrum*, *Pediastrum* and *Ophiocytium* Table III furnish evidences that these algae were more abundant during November and December forming 20.0% and 17.3% respectively, and low during July and August forming 3.0% and 4.3% respectively (Fig. 10-B). Fairly good quantities of green algae also occurred in the gut of the fish during January and February. Chatterji *et al*. (1977b) also observed high percentages of these algae during January, March, April, May and December and low during July in the guts of *Labeo gonius* collected from River Kali.

BLUE GREEN ALGAE (Myxophyceae)

Blue green algae also encountered in every month throughout the year. This group comprising of Polycystis; Coelosphaerium; Oscillatoria; Anabaena; Nostoc; Merismopedia; Tetrapedia; Arthrospira, and Phormidium. Out of these, Polycystis was the main component in comparison to other genera of blue green algae encountered in appreciable quantities in all the months except September, when this group of algae was dominated by Coelosphaerium; Anabaena and Tetrapedia. Scarcity of blue green algae was observed from August to November when only two genera were encountered (Table III and Fig. 10-C).

DESMIDS

Closterium, Desmidium, Cosmarium, Netrium, Docidium and Staurastrum constituted the small portion of the food of M. corsula. These are not the regular component of the gut content. Only Closterium formed a regular component of the gut content (Table, III and Fig. 10-D). Other five genera were found to be completely absent during July, August, November and February.

ALGAL SPORES, ZYGOTES AND MACROVEGETATION

Relatively fewer fragments of higher aquatic plants were found in the guts of this fish. Macrovegetation included portions of higher aquatic plants occurred throughout the year.

Abundance of macrovegetation was noticed in July and then it decreased from August onward (Fig. 11-A). Besides, a portion of diet of *Mugil corsula* was constituted by the algal spores and zygotes. They are consumed approximately throughout the year. The percentage of such items was, however, less than 30% in winter, but July, August and September were favourable months for their presence (Table III). It is also noted that when diatoms and algal food were abundant (December and February) higher aquatic plants were not found in the stomach of the fish. Sarojini (1954) also reported algal spores occasionally in small numbers especially during August and September in *Mugil parsia*, which is most abundant mullet in the estuaries of Bengal and extensively cultivated in brackish water bheris and freshwater tanks. Khan and Siddiqui (1973) have also found a good percentage of algal spores and macro-vegetation in the diet of *Labeo rohita* and *Cirrhina mrigala* but little amount in the food of the surface feeder, *Catla catla*. Chatterji *et al*. (1977b) have also reported algal spores, zygotes and macrovegetation in the guts of *Labeo gonius*.

ZOOPLANKTON

Zooplankton were noted in very low percentages (Table III). These low percentages show that the fish feed occasionally on zooplankton. It may be mentioned here that they may be accidently swallowed by the fish while feeding on algae, diatoms and decayed organic matter. The important constituents of zooplankton were protozoans, rotifers, copepods and cladoceran. The maximum quantity occurred in the month of November and January. Diminution in quantities can be seen from the Figure-12 during July, August, September and February. Phacus and Euglena occurred regularly in the winter months except in February. Among zooplankton, protozoans formed the most dominant group, copepods and rotifers being next in importance.

SAND AND MUD

Sand grains and mud formed regular items in the gut content of all the fishes. It formed 28.7% of the bulk of food and occurred in the gut throughout the period of investigations (Table, III and Fig. 11-C) shows that during all the months except November, December and January, almost all the specimens examined had high percentage of sand grains invariably mixed with algae and diatoms. It appeared in high percentage during rainy season. Pillay (1953) also reported sand grains forming about 16% of the total food of *Mugil tade*. The largest quantity of it encountered in April and May, while samll quantities were found in July and August. He explained that in October the abundance of algal food in the guts was correlated with the abundant growth of algae on bottom and marginal areas of the brackish water farm. Due to abundance of algal food in the beginning of the winter, the fish had no need to scrape or swallow mud to obtain its quota of algal food, and hence the complete absence of sand grains and mud was found in the guts during these months. However in *Mugil corsula*, sand grains were neither completely absent nor showed a high percentage.

Khan and Siddiqui (1973) reported that sand and mud are only important in the diet of *Cirrhina mrigala* and not to *Labeo rohita* and *Catla catla* which are column and surface feeders respectively. Pillay (1953) noticed that quantities of sand taken into the stomach increases with the growth of the fish. Romer and McLachlan (1986) also described that in mullets the percentage frequency of occurrence of sand grains in stomach is increased with further growth of the fish.

The percentage composition of each item of food in the dietary of the fish during different months of the year, as shown in Table III, indicates that decayed organic matter forms main part of the food throughout the year. The percentages of decayed organic matter, diatoms, algae and other food items consumed vary in different months. Sarojini (1954) has observed that these percentages vary in different environmental conditions. In the sea, the amount of decayed organic matter consumed, in rainy season was very low, but was high in the winter season, especially in the month of February. Contrary to this, in the estuarine environment, large quantities of this type of food were eaten during the rainy months and only small amounts were eaten during winter. Same type of fluctuations, as reported in estuarine and brackish water farms, were also noted in the present work. Large quantities of decayed organic matter encountered in rainy season and low in winter.

Diatoms figure next in importance, forming a major part of the gut content. They were invariably found along with sand grains and decayed organic matter which indicate that they were consumed from the bottom zones. Fluctuations in the percentages of diatoms in different months are very similar to those of the Labeo gonius (Chatterji et al., 1977b) from river Kali. Both feed at bottom and suck in diatoms. They show high percentages during the winter and low in rainy season. Next to decayed organic matter, diatoms formed the chief food of both fishes, Mugil corsula and Laboe gonius. Pillay (1953) found relatively fewer diatoms in the gut of Mugil tade collected from estuarine and brackish water farms. Romer and McLachlan, (1986) findings suggested that southern mullet, Liza richardsoni (Smith), at Sundays River beach utilized surf diatoms taken from the air water interface as a principal source of food throughout the year.

Regarding algae (Chlorophyceae and Myxophyceae), remarkable fluctuations can be found in the quantities consumed in different months. Winter forms the peak period of their abundance in diet, while there was scarcity of algae in rainy season. Contrary to our findings in freshwater, Sarojini (1954) found in brackish water and estuarine environment diminution of algae in winter months. She also recorded fairly good quantities of algae in the gut of mullet (_M. parsia_, and _M. speigleri_) in the months of May and June from marine environment. Pillay (1953) and Sarojini (1954) gave a detailed account of food and feeding habits of _Mugil tade_, _Mugil parsia_ and _M. speigleri_ from three different environments. They found that the algae appears to be a favourite item of mullet food and formed a very dominant constituent of the food.

Regarding zooplankton, a regular pattern of fluctuations in the abundance in the gut contents is not noticeable when the data for different months were considered together. According to Sarojini (1954) this probably, is only to be expected if they are voluntarily eaten by the fish. Present study on _Mugil corsula_ has also been able to corroborate this. Somewhat similar is the pattern of prevalence of sand grains and mud. The main fragments of zooplankton were protozoans, rotifers, copepods and cladoceran. Their abundance can be correlated with the presence of thick growths of algae and diatoms on the marginal areas or the benthic zones of these water areas, and the fact that much sand and mud may not have to be ingested by the fish while feeding on these growths.

Chatterji (1974) explained the variations in the occurrence of various food items recorded in different months of the year. Such variations are due to varied production of the food items in the environment. The percentage of food items varied from month to month and a particular type of food item tends to be maximum at a particular time, and this is due to succession of species in the population. The occurrence of phytoplankton in the guts of this species was recorded throughout the year, although the total percentage of phytoplankton was altogether affected during different months. It was noted that if the occurrence of one group is in lesser quantity, the other group of food item occurred in high proportions so as to compensate the decrease of the other. During monsoon months degradation of plankton was noted along with quite high percentages of decayed organic matter. It appears that the rivers are loaded with organic matter during these months and their source is incoming flooded water containing large amount of silt and mud. The percentage of decayed organic matter was quite low during winters. On the other hand, algae and diatoms dominated the food of the fish during winter months. The availability mainly depends upon the habit, taste, size of the food organism and the habit and size of the fish (Khan, 1972).

It is also observed in the present work that there was no particular preference for any particular food item. Bhatnagar and Karamchandani (1970) and Chatterji (1974) have also reported similar condition in the case of *Labeo fimbriatus*, *Labeo bata* and *Labeo gonius* respectively. Prakash (1962) has found in Salmon that its food changes with its locality and time (season), and sometimes when the normal food was not available, salmon would feed on alternate food. Ivlev (1961) suggested that the tendency of particular animal to consume certain food item in comparison to others, is determined by its inherent properties.

INTENSITY OF FEEDING

Feeding intensity or rate of feeding keeps on changing according to change in season, rain fall, diurnal variations in phisco-chemical conditions, growth and maturity etc.

To express intensity of feeding, gastro-somatic index (alimentary canal weight as percentage of body weight) was determined.

INTENSITY OF FEEDING IN RELATION TO SEASON

Gastro somatic indices of *Mugil corsula* along with the percentages of empty guts are given in Table (IV) and represented graphically in Figures (13-A and B). The values of gastro-somatic indices were found to be inversely proportional to the percentage of empty guts. High feeding intensity was recorded in winter. From January onwards the feeding intensity declined and reached to its lowest level during the monsoon months (July and August). Peak period of active feeding was recorded in September and November especially females showed high active feeding during this period and may, therefore, be considered a reliable proof of an intensive feeding period (Fig. 13-A). As pointed out in the discussion on the seasonal fluctuations in the composition of food of Mugil corsula, large quantities of diatoms and algae were eaten up by the fish during winter season and this behaviour may be due to the availability of these food materials in considerable quantities in the environment. A noticeable reduction in the feeding intensity is denoted by the large number of 'empty' stomach and those containing only traces of food materials, in fish caught in the rainy months (July and August). This condition has also been observed by Sarojini (1954) in Mugil parsia caught from three different environments. She explained that it appears probably that during the rainy season, the bottom flora in these environments (Marine, estuarine and brackish water) are greatly disturbed by the incoming flood waters and their growth is hampered. This might be the reason for the small quantities of food consumed by the fish during that period.

INTENSITY OF FEEDING IN RELATION TO SIZE

The average feeding intensity and percentage of empty guts at each size of Mugil corsula are given in Table V and shown in Figure (14). It may be noticed from the observations that the rate of food intake increased as the fish increased in size and reached to the highest level in size range (31-35 cm). Afterwards, the feeding intensity decreased and continued at a moderate rate. Contrary to feeding intensity, the percentage of empty guts was found decreasing as the fish increased in size.

FEEDING HABIT

By studying the food of *Mugil corsula* as discussed before it was found that decayed organic matter, diatoms and algae form the main food of the fish. The presence of large quantities of mud and sand grains in these guts have indicated that these food materials are actually consumed from the bottom. Though the presence of certain diatoms and planktons in the guts could be explained as having been picked up from what is known as the iliotrophic layer (as cited by Sarojini, 1954) on the substratum of their habitat where these organisms settle down at certain times. It is, therefore, concluded that the grey mullet, *Mugil corsula* is an iliophage (an animal which obtains food from the mud, consisting of benthic plant and animal life together with organic particles forming a layer known as the iliotrophic layer on the substratum of muddy bottom). The fact that the guts of specimens examined invariably contained mud mixed with algal matter also clearly show that the zone of feeding is not the surface or the mid-water. The fish possess an inferior mouth and a dorso-ventrally compressed conical head, a shape admirably suited for feeding at the bottom or in littoral bottom areas. Mugil corsula has also a prominent symphysial knob in lower jaw which according to Hora (1939) helps the fish in nibbling on attached algae. A muscular gizzard like structure is also found at the end of the pyloric end which according to Khanna (1961) is helpful in crushing the food. The food of these species includes large quantities of sand, mud, organic matter and other organisms having hard covering like diatoms crustaceans, insects etc. obtained from the river bottom. Such muscular gizzard, therefore, appears to be an adaptation for such a diet.

The observations recorded here are in broad agreement with the findings of Pillay (1953), in Mugil tade and of Sarojini (1954) in Mugil pargia and Mugil speigleri. From the detailed study of food habits of these species of mullets, it has been found that decayed organic matter, algae and diatoms formed the main food of the fish. The presence of mud and sand in almost every stomach and the comparison between the gut contents and the algal and diatom growths on the muddy bottom of the habitat have indicated that these food materials are actually consumed from the iliotrophic layer. Sarojini (1954) has also considered necessary to varify the mode of feeding of Mugil parsia and Mugil speigleri from actual observation on the fish in aquarium with growths of algae and diatoms on a layer of mud at the bottom. Plankton were also introduced in aquaria and it was observed that the adult mullets preferred algae and diatoms on the mud, discarding the floating plankton organisms. On the contrary, examination of the gut contents of post-larval and Juveniles of M. parsia ranging in size from 5 mm to 22 mm showed that the young of this species feed at or near the surface.

The feeding activity of the fry of Mugil tade was also observed in aquaria by Pillay (1953) into which were introduced pieces of wood and stones having thick growths of algae on them. He observed that the fish feed or nibble readily on the slimy algae, more particularly the soft decaying filaments. As between submerged algal growths and iliotrophic layers placed on purpose within their reach, the fish seldom preferred the latter. But in the absence of such food they nose about in the mud, sucking in the decayed matter or accumulations of algae.

From all these observations it is seen that there is a gradual change over from surface feeding habit of the post larvae to bottom feeding habit of the adult. Sand grains and decayed organic matter appeared in appreciable proportions in the guts of fingerlings and it may be considered as the beginning of adult feeding habit. Unlike the fingerlings and the adults, the fry seem to feed on the surface plankton as those of many other species like Mugil troscheli and Mugil waigiensis (Chidambaram and Kuriyan, 1952), Mugil dussumeri and Mugil caeruleomaculatus (Kuthalingam, 1957), Liza macrolepis and Mugil cephalus (Luther, 1962).

The present observations on Mugil corsula for bottom feeding habit, support the observations made by Kuthalingam (1957) for Mugil dussumeri and M. caeruleomaculatus, Luther (1962) for Liza macrolepis and M. cephalus, Prasadan (1970) for Mugil macrolepis. These species obtain their food from the substratum of their habitat.

The observations made in the present work are at variance with those of Hora (1939), Bhimachar (1945) and Sarojini (1951). Hora (1939) pointed out the importance of anatomical study of the mullet Mugil corsula and elucidated the structural adaptation and modification that have been brought about by its surface feeding habit. He stated that aerial vision was acquired under estuarine condition during the transition period from marine to freshwater life, as an adaptation for feeding on floating matter. He suggested that the prominent symphysial knob of M. corsula probably helps in uprooting algae from the shores. Hora described that Mugil corsula is little different from that of other members of the group. This species feeds on filamentous algae floating on the water surface. Insects and young molluscs entangled among the algal filaments are also taken in. Small specimens of 6 to 8 cm length subsist mostly on copepods and small insects. In confined waters, however, M. corsula is stated to exhibit browsing habit also. In the present study, however, no instance has ever been noted of the fish preying upon insects nor were any insect remains detected in the gut contents as described by Hora (1939). According to Bhimachar (1945) and Sarojini (1951) the stomach contents of several adult specimens contained nothing but algae, few insects and young molluscs entangled among plants. When there were swarm of insects, M. corsula feeds voraciously on insects. While in the present investigation, insects were completely found to be absent having only high percentages of decayed organic matter, diatoms and algae which are found in bottom. In few months, copepods, cladoceran and rotifers were also observed.

Present observations are in broad agreement with that expressed by Ranganathan and Natarajan (1969) for Mugil corsula collected from Krishnagiri and Sathanur reservoirs of Tamil Nadu. According to them, Mugil corsula is predominantly a mud feeder and characterised by the presence of longer gut and muscular bulb at pyloric end. The species consumed large quantities of sand or mud and the organic matter. They observed that the spent specimens were found gorged with fine bottom scum indicating voracious feeding soon after spawning. Mugil corsula is also capable of surface feeding. The aerial vision and the position of the mouth just near the water surface aid in gulping floating materials.

FIG. 9-A - ALIMENTARY CANAL OF M. CORSULA (HAM.)

Oes.	:	Oesophagus
GZ.	:	Gizzard
Stm.	:	Stomach
Pyl. Caeca	:	Pyloric Caeca
Int.	:	Intestine

FIG. 9-B - BUCCAL CAVITY OF M. CORSULA (HAM.)

Ul.	:	Upper Lip
Ll	:	Lower Lip
N	:	Notch
T	:	Tubercle
F	:	Folds

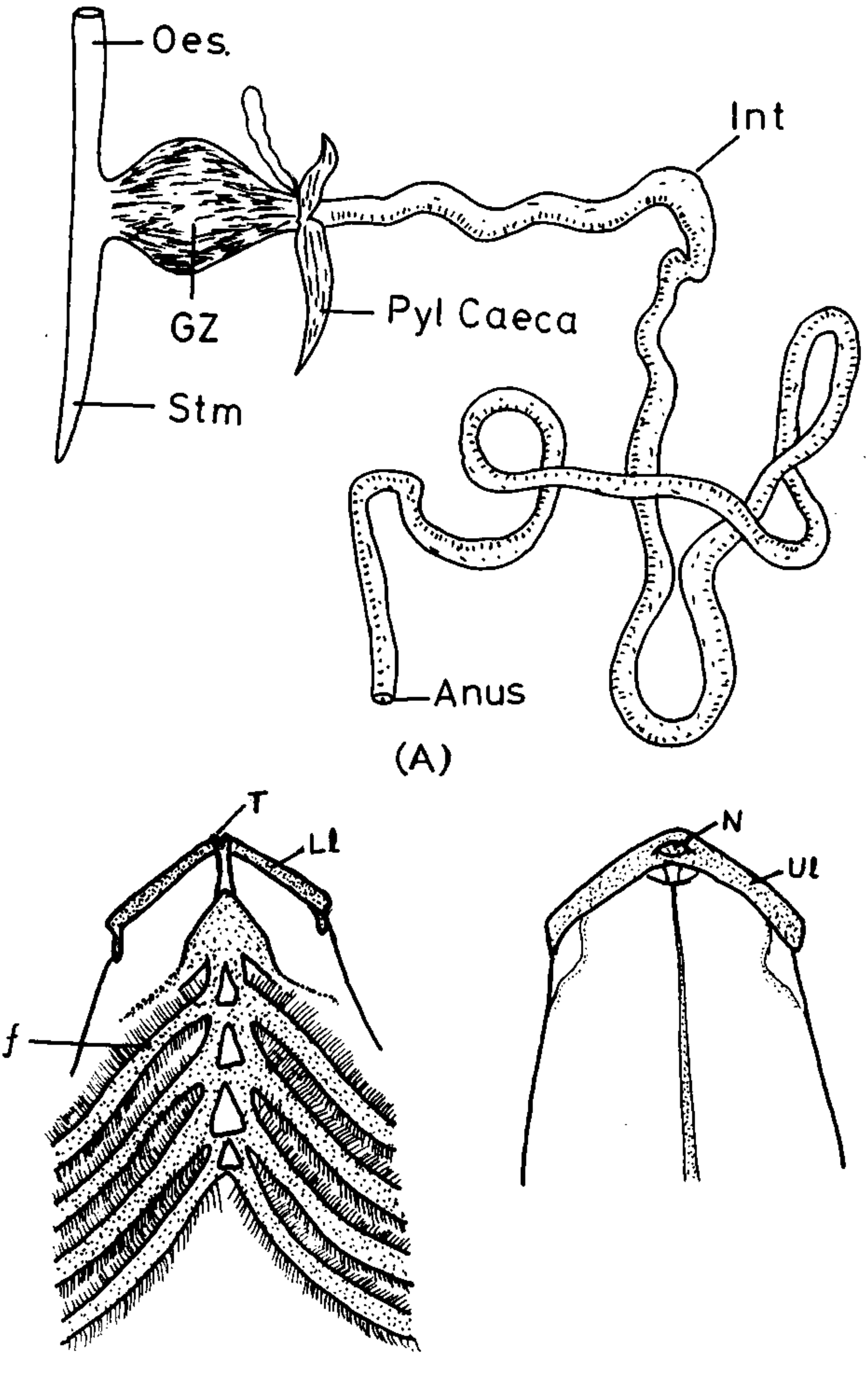


Fig. 9 (A,B)

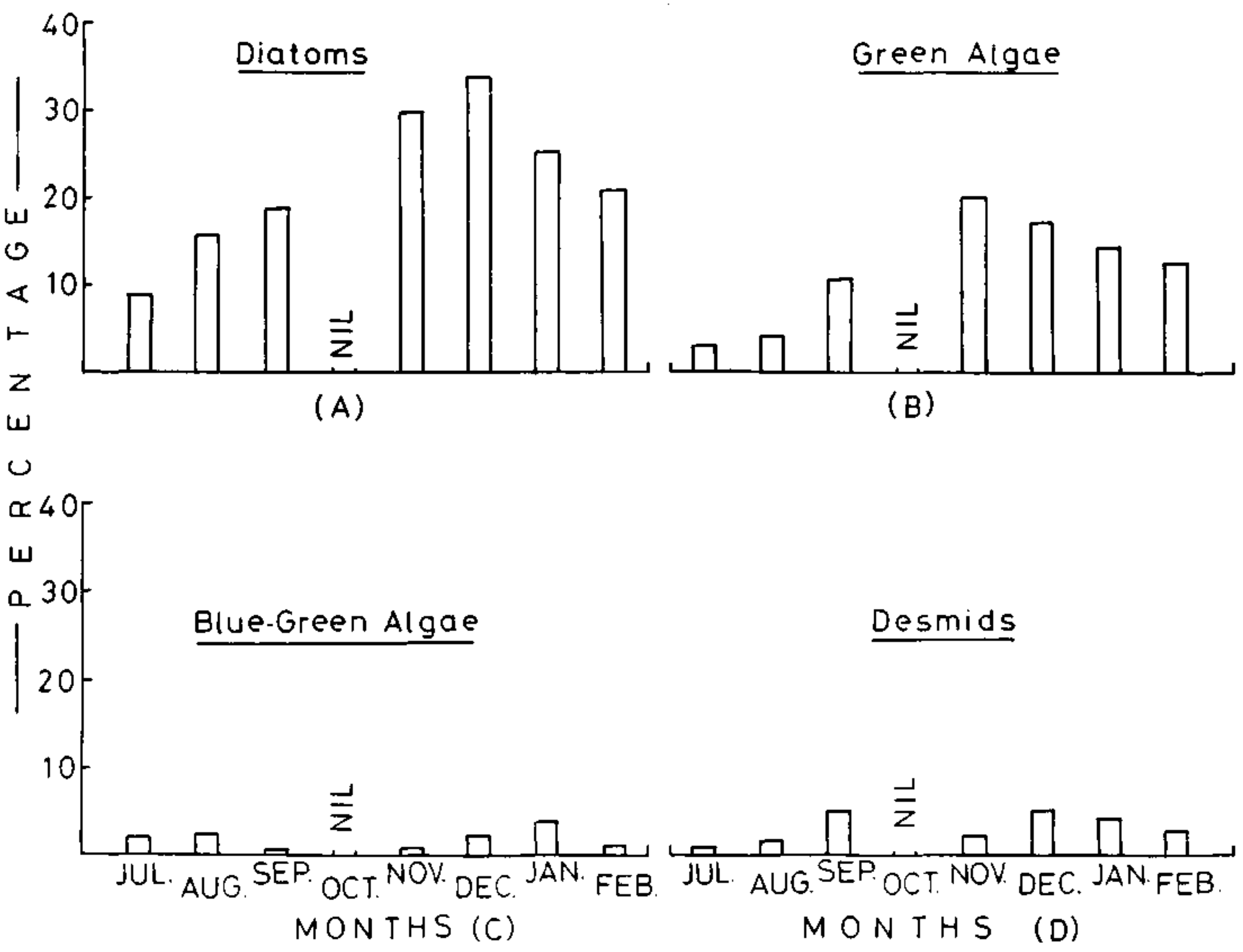
Table - IV Seasonal Variations in the Intensity of Feeding

MONTHS	MALE		FEMALE	
	G.S.I.	% Empty Guts	G.S.I.	% Empty Guts
July	3.13	61.53	3.39	53.84
August	3.44	46.66	3.25	46.15
September	4.77	25.00	5.13	16.66
November	5.12	-	5.78	-
December	4.48	10.00	4.33	-
January	3.29	14.28	3.53	11.11
February	2.93	4.76	3.36	-

Table - V Variations in the Intensity of Feeding with Size

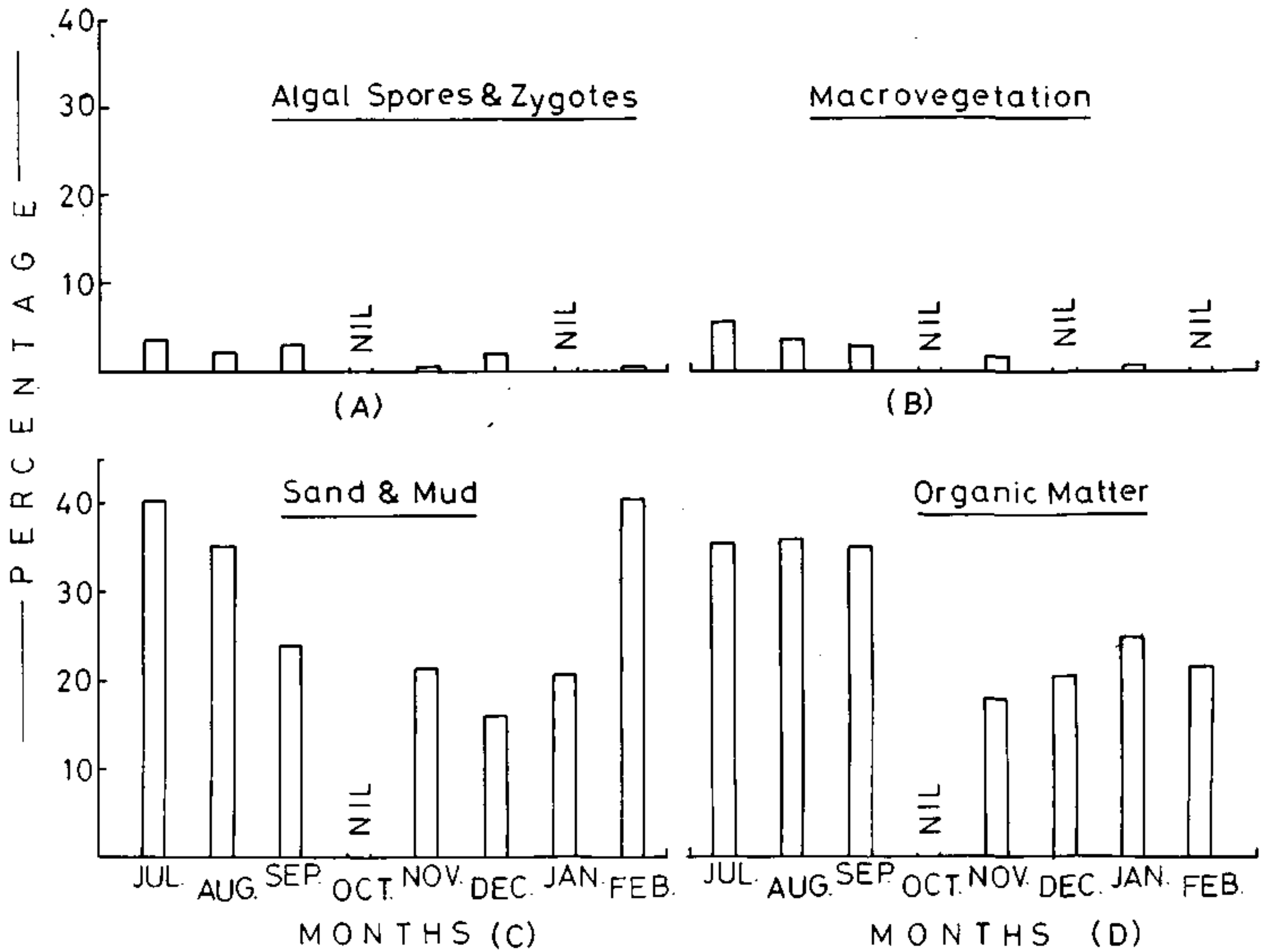
SIZE GROUPS (cm)	G.S.I.	% EMPTY GUTS
15-20	3.40	25.00
21-25	3.21	31.18
26-30	4.07	7.69
31-35	4.83	-
36-40	3.57	-

FIG. 10-12 - SHOWING SEASONAL VARIATIONS IN FOOD CONTENT OF *M. CORSULA* (HAM.)



PERCENTAGE
40
30
20
10
Diatoms
NIL
(A)
Green Algae
NIL
(B)
40
30
20
10
Blue-Green Algae
NIL
JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB.
MONTHS (C)
Desmids
NIL
JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB.
MONTHS (D)

Fig. 10 (A-D)



Algal Spores & Zygotes
Macrovegetation
Sand & Mud
Organic Matter
PERCENTAGE
40
30
20
10
NIL
(A)
(B)
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
JAN.
FEB.
MONTHS (C)
MONTHS (D)

Fig. 11 (A-D)

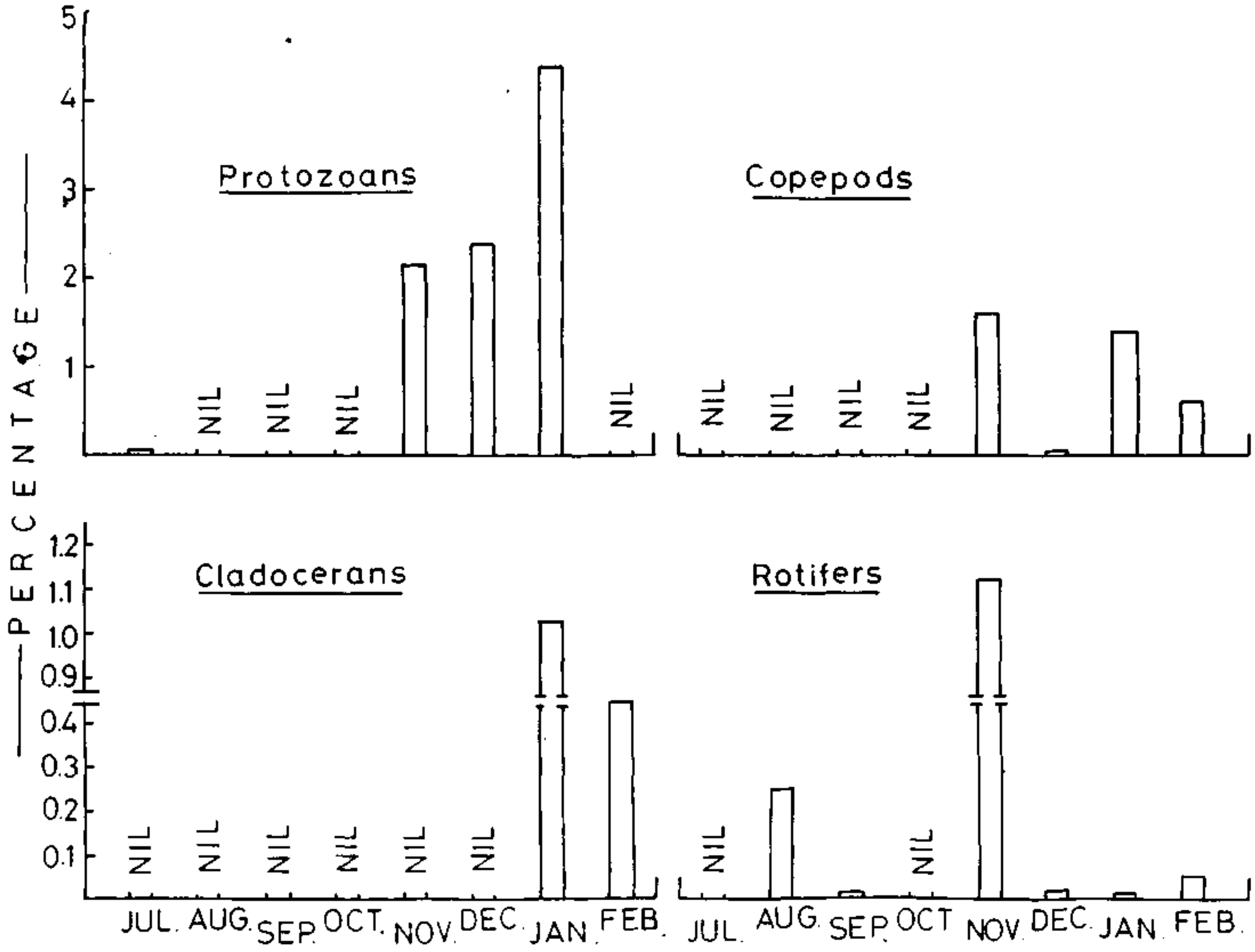

PERCENTAGE
Protozoans
Copepods
Cladocerans
Rotifers
NIL
5
4
3
2
1
1.2
1.1
1.0
0.9
0.4
0.3
0.2
0.1
JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB.
JUL. AUG. SEP. OCT NOV. DEC. JAN. FEB.

Fig. 12

FIG. 13 - SEASONAL VARIATIONS IN THE INTENSITY OF FEEDING

A	-	Female (♀)
B	-	Male (♂)
G.S.I.	-	Gastro-Somatic Index
E.G.	-	Empty Gut

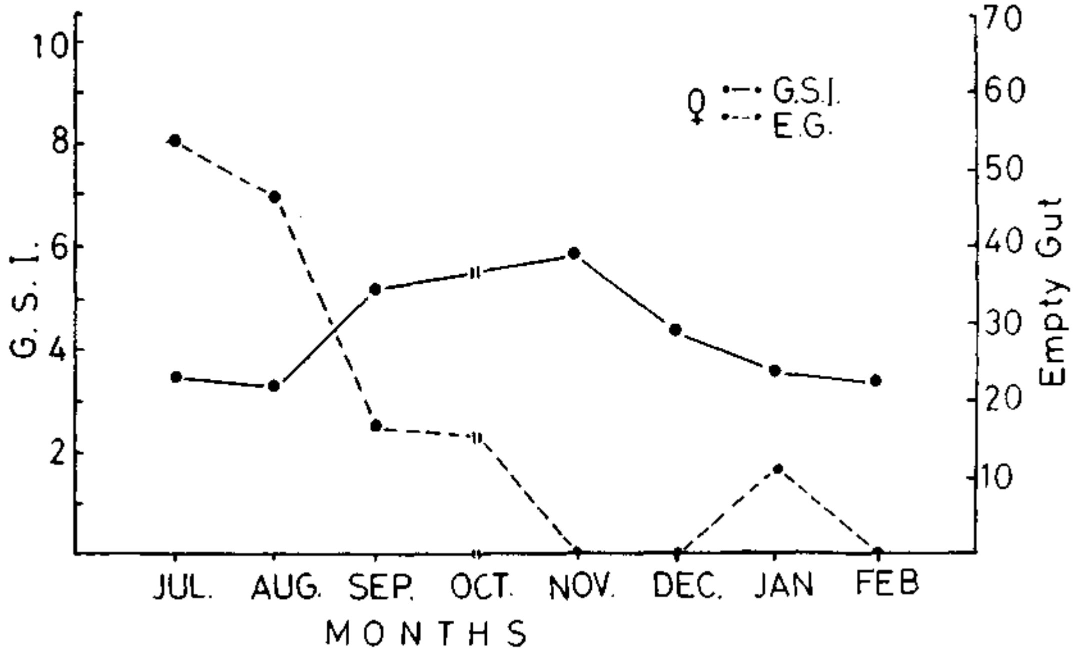


Fig. 13-A

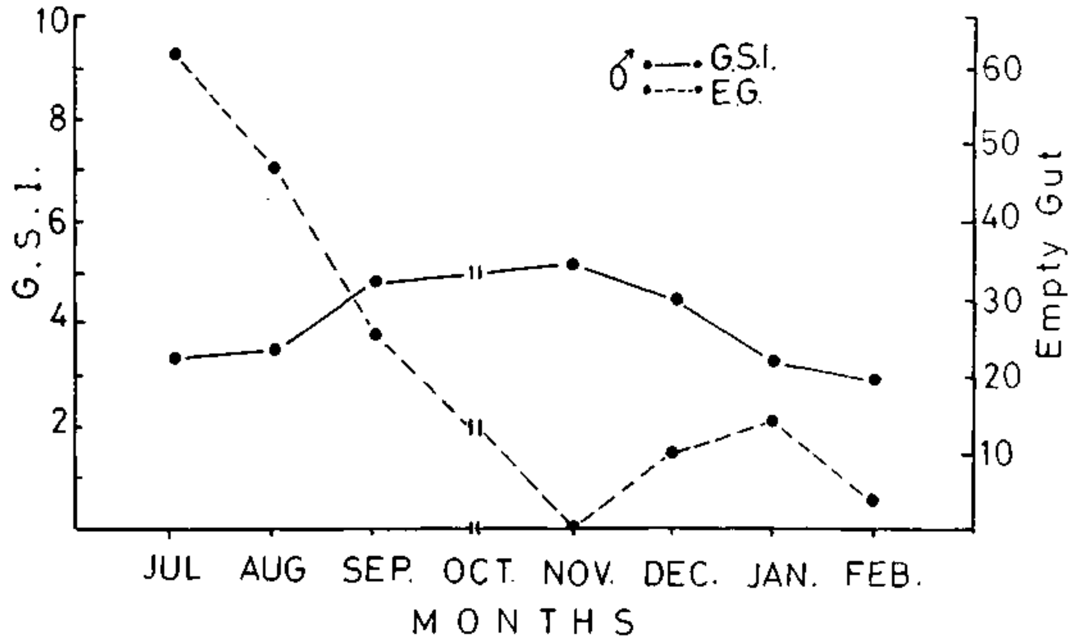
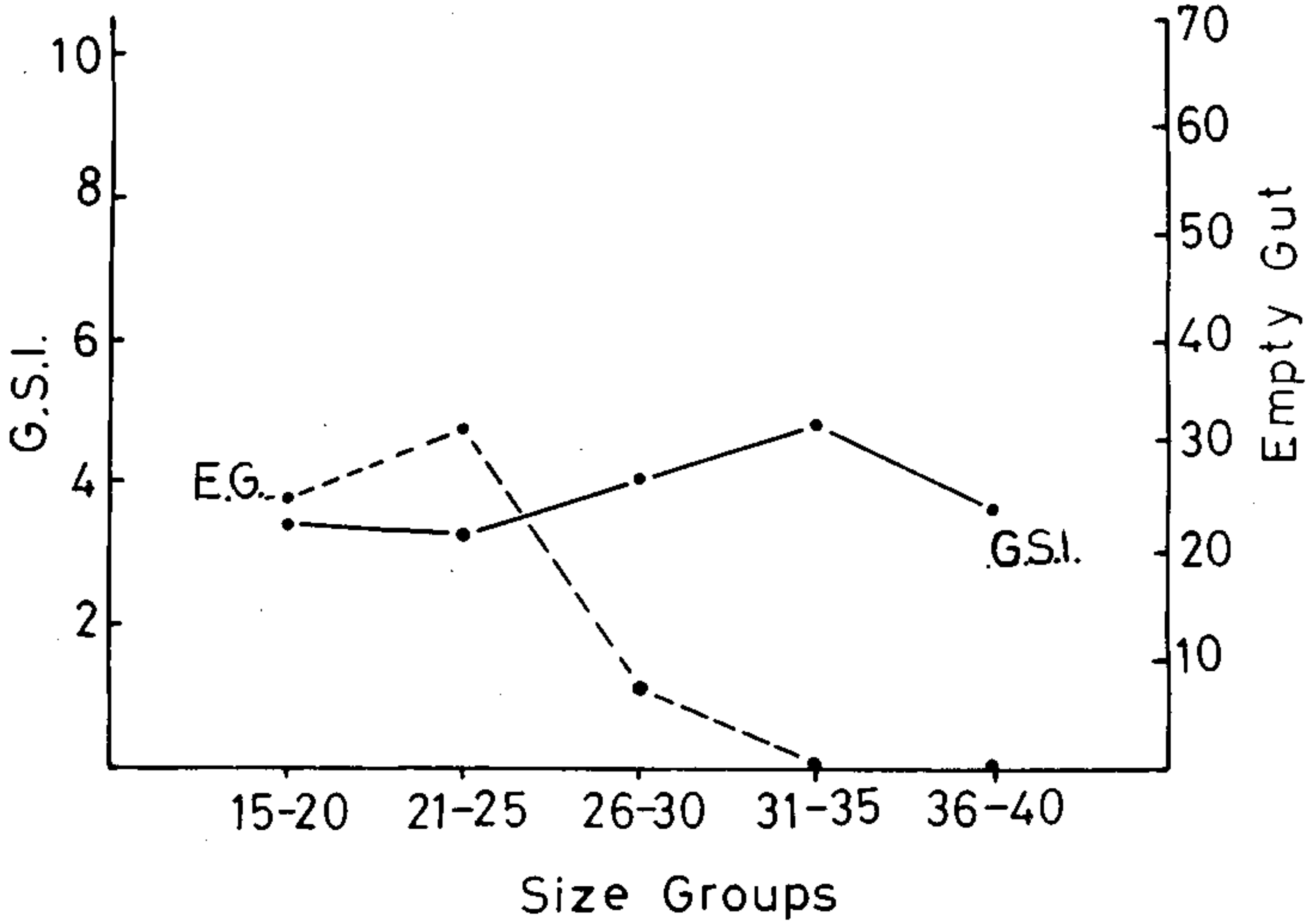


Fig. 13-B

FIG. 14 - VARIATIONS IN THE INTENSITY OF FEEDING WITH SIZE.

G.S.I. - Gastro-Somatic Index

E.G. - Empty Gut.


10
8
6
4
2
G.S.I.
70
60
50
40
30
20
10
Empty Gut
E.G.
G.S.I.
15-20
21-25
26-30
31-35
36-40
Size Groups
Fig. 14

SUMMARY

Inland fishery resources of India have played a very important role in human nutrition. The increase of fish production in inland water entirely depends on the proper management of the fishery resources, and one of the important aspects of the fishery management is the knowledge of the natural history of the fish to be cultured in these inland waters. It is a part of ecology dealing with biology of the fishes. This study is a pre-requisite in the management and exploitation of the fishery resources. A review of literature shows that most of these studies are confined to marine food fishes, estuarine fishes, freshwater carps, murrels and cat fishes. Few workers have also studied the various aspects of biology of mullets which are regarded as important food fishes of India. All of these studies are preliminary in nature and no comprehensive work has so far been done on mullets. It is, therefore, an attempt to make a detailed study on the biology of one of the species of mullets, _Mugil corsula_ (Hamilton). At present two aspects of biology, namely morphometric study and food and feeding habits, have been taken into consideration to fulfill the requirements of M.Phil. degree.

In order to have rational basis for the management and exploitation of the fishery resources, we must have a good knowledge of species composition of an ecosystem supporting the fishery. The taxonomic intraspecific varitions in the fish over the area of investigation is potentially an important matter from the stand point of future management. In the present investigations, studies to assess the growth rate of morphometric characters in relation to each other and to resolve the possibility of great differences between the regression of body parts of males and females from a single environment (river Jamuna) are carried out. The characters selected for the study were total length, standard length, forked length, depth of body, head length, width of the head, inter-orbital width, length of caudal peduncle, pre-dorsal length and gut length. The regressions of different body measurements on total length were carried out and almost a linear relationship was noted in the fishes of single environment. While comparing the different characters of male and female, significant differences were found in their measurements. The observed values suggest that the relative growth of both sexes was not same in all the morphometric parameters and the fish exhibited significant sexual diamorphism.

Another aspect of biology taken into consideration to complete this dissertation was food and feeding habit. The study of food and feeding habit of fish is an important aspect of biology. *Mugil corsula* (Ham.) feeds mainly on plankton along with large quantities of sand or mud and the decayed organic matter. The presence of these food items showed a bottom feeding habit of the fish. The intensity of feeding was found to be maximum in winter. From January onwards the feeding intensity declined and reached to its lowest level during monsoon months. It was also recorded that the rate of food intake increased as the fish increased in size and reached to the highest level in size (31-35 cm). Afterwards, the feeding intensity decreased and continued at a moderate rate. Percentage of empty guts was also determined.

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